RECORDS

OF THE

SURVEY OF INDIA

Volume VII

ANNUAL REPORTS OF PARTIES AND OFFICES

1913-14

From 1st October 1913
To 30th September 1914

PREPARED UNDER THE DIRECTION OF

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CONTENTS.

PART I.—TOPOGRAPHICAL SURVEY.

REPORTS FROM THE NORTHERN CIRCLE.

REPORTS FROM THE SOUTHERN CIRCLE.

REPORTS FROM THE EASTERN CIRCLE.

PART II.—GEODETIC AND SCIENTIFIC OPERATIONS.

PART III.—SPECIAL REPORTS.

ILLUSTRATIONS.

MAPS.

(at end of Volume, with the exception of No. 12).

APPENDIX.

RECORDS OF
THE SURVEY OF INDIA.

PART I.—TOPOGRAPHICAL SURVEY.

NORTHERN CIRCLE.

(*Vide* Index Maps 1 and 4.)

Summary.— Four field parties worked in this Circle, and in October 1913, a small detachment was formed for a large-scale survey of Simla. During the past field season a total area of 23,625 square miles was surveyed consisting of :—

	Square miles.
Survey 2-inch	33
Survey 1-inch	2,652
Resurvey and Supplementary Survey 1-inch	8,638
Revision Survey 1-inch	11,308
Revision Survey ½-inch and ¼-inch	994

The Riverain Detachment carried out a total of 2,435 linear miles of traversing over an area of 485 square miles for the riverain work, and 4,162 linear miles of traversing over an area of 959 square miles for the Khushāb Thal, Kāngra and Gujrāt rectangular work.

No. 20 Party surveyed an area of 13,722 acres in various cantonments during the year.

Lieutenant-Colonel C. L. Robertson, C.M.G., R.E., was in charge of the Circle up to the 5th October 1913, and Colonel W. J. Bythell, R.E., then held charge up to the end of the Survey year.

No. 1 PARTY.

By Mr. M. C. Petters.

PERSONNEL.

Imperial Officers.

Major A. A. McHarg, R.E., in charge up to 8th September 1914.
Major M. O'C. Tandy, R.E., in charge from 9th September 1914.
Lieutenant H. M. McKay, R.E., attached to 20th August 1914.

Provincial Officers.

Mr. H. H. B. Hanby.
„ P. A. T. Kenny, from 1st September 1914.
„ E. B. West.
„ D. K. Rennick, to 10th November 1913.
„ R. C. Hanson.
„ H. T. Hughes, from 26th January 1914 to 10th September 1914.
„ W. J. B. Miller.

Upper Subordinate Service.

Mr. Sher Jang, K.B., to 26th November 1913.
„ Natha Singh, R.S.
„ Paras Ram, to 12th November 1913.
„ Jamna Prasad, to 9th March 1914

Lower Subordinate Service.

34 surveyors, etc.

The field head-quarters of the party opened at Siālkot on 1st November 1913 and reopened on 6th April 1914 at its recess head-quarters in Mussoorie.

The area under survey lay in the North-West Frontier Province, Kashmīr and Jammu State, and the Punjab, including the districts of Dera Ismail Khān, South Wazīristān, Ladākh, Riāsi, Mīrpur, Udhampur, Jammu, Jasrota, Pūnch State and Siālkot. Except for an area of about 500 square miles of flat country bordering on the plains of the Punjab, the nature of the country was generally mountainous and wooded.

Operations in the field and map drawing continued throughout the year.

Topography.—The area surveyed on the scale of 1-inch to 1 mile was 2,652 square miles, and comprised the following sheets :—

The whole of —	Parts of—
$43\ \frac{L}{10,\ 13,\ 14.}$	$43\ \frac{K}{2,\ 5,\ 6,\ 7,\ 11,\ 12,\ 15,\ 16.}$
$43\ \frac{P}{1,\ 2.}$	$43\ \frac{L}{9.}$
$39\ \frac{I}{1.}$	$43\ \frac{N}{2.}$
	$43\ \frac{O}{3,\ 4,\ 7.}$

The surveyors were divided into 4 camps. Mr. H. H. B. Hanby was in charge of sheets $43\,\frac{L}{10,\,13,\,14}$, $43\,\frac{P}{1 \text{ part of}}$, $43\,\frac{P}{2}$ and $43\,\frac{L}{9 \text{ part of}}$; Mr. E. B. West of $39\,\frac{I}{1}$, Mr. D. K. Rennick of the remainder of $43\,\frac{K}{2,\,5,\,6,\,7}$ and $43\,\frac{L}{9}$, and Messrs. H. T. Hughes and P. A. T. Kenny successively of part of sheets $43\,\frac{K}{11,\,12,\,15,\,16}$ and $43\,\frac{O}{3,\,4,\,7}$. Mr. H. H. B. Hanby also tested work in sheets $43\,\frac{L}{1,\,5 \text{ and } 9}$ in season 1912-13, which owing to omissions and alterations to boundaries will require revision during the winter of 1914-15. Major A. A. McHarg, R.E., personally supervised the work done by Lieutenant H. M. McKay, R.E., in $43\,\frac{P}{1}$ north.

The nature of the ground under survey varied in character from low-lying flat country on the south, bordering the plains of the Punjab, to the high ranges of the Pīr Panjāl on the north covered with pine forest. In addition, areas of 125 square miles in sheets $43\,\frac{N}{5,\,6}$ and 869 square miles in sheets $43\,\frac{N}{9,\,10,\,13,\,14}$, on the half-inch and quarter-inch scales respectively, were revised in district Ladākh. Further, 33 square miles were surveyed on the two-inch scale, embracing Jammu town and the more intricate country in its immediate vicinity. One surveyor was employed for close on a month on the survey of the alignment of the Mandra-Chakwāl-Bhaun Railway at present under construction, to allow of its insertion in the included Degree sheets.

Triangulation.—The total area triangulated in the party was 2,677 square miles. Mr. E. B. West triangulated 300 square miles in Dera Ismail Khān district and South Wazīristān for the survey of $39\,\frac{I}{1}$. The computations were done in the field and the detail survey included in the programme of the party. Mr. R. C. Hanson triangulated 627 square miles in sheets $43\,\frac{P}{3,\,4,\,7}$. The country was undulating in sheets $43\,\frac{P}{3,\,7}$ and densely covered with trees. Many stations had to be built on the tops of houses. Mr. W. J. B. Miller triangulated 1,750 square miles in sheets $43\,\frac{O}{12,\,14,\,15,\,16}$, $43\,\frac{P}{9,\,10,\,11,\,13,\,14,\,15}$, $52\,\frac{O}{2,\,3,\,4,\,8}$ and $52\,\frac{D}{1,\,2}$. The country was thickly wooded, mountainous and sparsely inhabited towards the north.

Traversing.—Mr. R. C. Hanson did 98 linear miles of height traverse in sheets $43\,\frac{P}{4,\,7,\,8}$.

Recess duties.—During the year sheets $43\,\frac{F}{6,\,9 \text{ and } 13,\,10}$, $\frac{J}{2,\,6,\,10,\,14,\,15}$, $\frac{N}{3,\,8}$ and $\frac{O}{2}$ were submitted for publication.

The computations of the areas triangulated and traversed by Mr. R. C. Hanson have been completed. The computations of the areas triangulated by Messrs. E. B. West, D. K. Rennick and Jamna Prasad, during season 1911-12, had to be revised to make them accord with the duplicate set prepared by No. 15 Party. No triangulation charts were prepared as no officer was available.

Two surveyors were deputed to the office of the Superintendent of the Trigonometrical Survey, Dehra Dūn, for a three months' course in the working of the field lithographic press.

Arrears of fair mapping.—The following sheets represent arrears of fair mapping on the 1-inch scale, and will be submitted for publication during 1914-15 :—Sheets $43\,\frac{J}{9,\,13}$, $\frac{K}{1,\,3,\,4,\,6,\,10}$ and $\frac{N}{1 \text{ and } 5,\,6,\,7}$.

Cost-rates :—

	Rs.	
Traversing for 1-inch detail survey, Kashmīr . . .	14·6	per linear mile.
Triangulation " " " " . . .	6·2	" square "
" " " " N.-W. F. Province .	36·7	" " "
2-inch detail survey, Kashmīr	38·4	" " "
1 " " " "	19·2	" " "
1 " " " N. W. F. Province .	25·0	" " "
½ " " " revision survey, Kashmir . . .	9·0	" " "
¼ " " "	0·9	" " "
Fair mapping 1-inch scale	5·3	" " "

The high cost rate of triangulation in the Shirāni country is due to the heavy transport charges of the major part of the militia and frontier constabulary escorts required for the completion of the triangulation and detail survey of that tract, being placed at the disposal of the triangulation detachment at the commencement of operations.

The total cost of the party was Rs. 1,10,403.

Health.—The health of party has been good throughout the season.

Inspection.—The party was inspected twice by the Superintendent, Northern Circle, once in the field and once during recess, and once by the Surveyor-General.

No. 2 PARTY.

By Mr. B. R. Hughes.

The field headquarters of the party opened at Hissār on the 3rd November 1913 and closed on the 20th April 1914, the recess quarters being at Mussoorie.

PERSONNEL.

Imperial Officers.

Captain G. F. T. Oakes, R.E., in charge from 7th October 1913 to 27th April 1914.

Captain F. B. Scott, I. A., attached from 11th November 1913 to 26th April 1914.

Provincial Officers.

Mr. B. R. Hughes in charge from 28th April 1914.

" T. W. Babonau from 5th October 1913 to 4th May 1914.

" F. B. Powell.

" Kanak Singh.

" R. E. Saubolle.

" E. C. O'Sullivan up to 14th September 1914.

" J. H. Johnson from 16th October 1913.

" F. W. Smith from 15th October 1913 to 14th September 1914.

" J. A. Calvert.

Lower Subordinate Service.

41 Surveyors, etc., in the field.

Average 33 in recess (excluding absentees).

Topography.—The outturn of the party was :—

		Square miles.
1 inch=1 mile Revision Survey	...	5,190
1 inch=1 mile Resurvey	...	1,514
Total	...	6,704

In sheets Nos. 43 $\frac{H}{15, 16}$, $\frac{L}{3, 4}$, 44 $\frac{I}{1, 5}$, $\frac{K}{14}$, $\frac{O}{2, 3, 5, 6, 7, 9, 10, 11, 12, 14, 15, 16}$, 53 $\frac{C}{3, 4, 7, 8, 11, 12, 15}$. Very small portions were surveyed in 53 $\frac{C}{16}$.

Surveyors were divided into four camps under Messrs. Babonau, Powell, Saubolle, and O'Sullivan.

During the field season the following surveyors were transferred to the Simla Detachment:— Faiz-ullah, Jalal-ud-din, Basant Singh.

The survey in sheets Nos. 43 $\frac{H}{15, 16}$, $\frac{L}{3, 4}$, 44 $\frac{I}{1, 5}$ was carried out by means of the system of rectangles laid down by the Canal Department, of 800 × 720 *karams*, sub-divided into 200 ×180 *karams*. At each corner of these rectangles was embedded a stone *in situ* which proved of immense help to the surveyors in not having to chain so frequently, and no doubt helped where the stones were laid accurately in turning out good survey, as against the system of only working from plotted trijunctions. No heights or contours were observed in the course of the survey, but the former were obtained from contoured canal maps and inserted in the field sections.

In sheets 44 $\frac{K}{14}$, $\frac{O}{2, 3, 5, 6, 7, 9, 10, 11, 12, 14, 15, 16}$, and 53 $\frac{C}{3, 4, 7, 8, 11, 12, 15}$ boundaries and detail, where of use, were taken from blue prints of old 1-inch maps, and traced on to field sections and checked on the ground.

Triangulation.—Captain Scott and Mr. Kanak Singh triangulated an area of 2,280 square miles for future detail survey on the 1-inch scale in portions of sheets Nos. 53 $\frac{D}{2, 3, 4, 7, 8, 12, 15, 16}$, $\frac{H}{4}$, and 54 $\frac{A}{1, 5, 9, 13}$, $\frac{E}{1}$.

Traversing.—Captain Scott, Inayat-ullah and Ahmad Husain Khan ran 738 linear miles of height traverse in flat country where no triangulation was found possible and no previous traversing had been done.

The country under survey consisted of flat plains, well cultivated and canal irrigated, interspersed with low sand hills.

Fair mapping.—All fair mapping of the 26 sheets surveyed during the field season will be completed and sent for publication before the party leaves for the field. The drawing was carried out under three drawing sections and one typing section. Instead of making 1½-inch blue prints from the 1-inch plane-table sections and having to transfer and adjust these on to fair sheets, a complete line trace was prepared for each sheet on the 1-inch showing graticules, guide lines for marginal typing etc.; these were photographed up to the 1½ and printed direct on to drawing paper.

The compilation and fair drawing of village boundaries in sheets $43\frac{L}{16}$ $44\frac{M}{1, 2, 3, 4, 6, 7}$, $44\frac{I}{6, 9, 10, 11, 13, 14, 15, 16}$ of the Amritsar district were also done, and sheets despatched to the Superintendent, Map Publication, a general section being detailed for this work.

Cost-rates.—Revision Rs. 9·67 per square mile, Resurvey Rs. 9·12 per square mile, Triangulation Rs. 5·55 per square mile, Traversing Rs. 8·23 per linear mile.

Health.—This was good throughout the season. Mr. Calvert after carrying out a part of the reconnaissance of Captain Scott's triangulation fell sick and proceeded on three months' leave.

Inspection.—The Superintendent, Northern Circle, inspected the party during the field season and also in recess.

The Surveyor General inspected the party in recess in September.

No. 3 PARTY.

BY CAPTAIN F. F. HUNTER, I.A.

The party was employed in the Punjab and United Provinces, with the exception of the work in the Simla district and Simla Hill States of the Punjab, and in the Himālayas near Mussoorie and the Siwālik Hills in the United Provinces, the nature of the country was flat.

PERSONNEL.

Imperial Officers.

Captain F. F Hunter, I. A., in charge from 28th April 1914.
Captain F. B. Scott, I.A., attached from 27th April 1914.

Provincial Officers.

Mr. J. O. Greiff, in charge up to 27th April 1914.
" J. A. Freeman, from 21st September 1914.
" E. J. Biggie.
" A. C. Bose.
" P. A. T. Kenny, up to 31st August 1914.
" A. J. A. Drake, up to 14th September 1914.
" F. H. Grant, up to 14th September 1914.
" H. T. Hughes, from 11th September 1914.
" F. J. Grice, up to 14th September 1914.
" Moqimuddin.

Upper Subordinate Service.

Mr. Mahomed Lutf Ali.
" Mahindar Singh, up to 10th August 1914.
" Muhammad Husain, promoted from Lower Subordinate Service from 1st June 1914.

Lower Subordinate Service.

63 Surveyors, etc.

The duration of the field season was from 1st November 1913 to 20th April 1914.

The health of the party was good.

Topography.—The country surveyed comprised, in the Punjab, parts of the districts of Simla, Ambāla, Karnāl, and Rohtak and parts of the following Simla Hill States: Bhajji, Dhāmi, Keonthal, Koti, Bāghal, Baghāt, Nālāgarh, Kuthār, Bijā, Mailog and Kunihār, and parts of Suket, Sirmūr, and Patiāla States; and in the United Provinces, parts of the districts of Dehra Dūn, Sahāranpur, Muzaffarnagar, Meerut and Garhwāl, and parts of Tehrī State.

The area is traversed in the north by the Sutlej and Giri rivers, in the west by the Jumna, and in the east by the Ganges river. It is intersected by numerous hill torrents in the hill and sub-montane tracts, and by a complicated irrigation canal system in the plains. Except in the hill portions which were heavily wooded, the greater part of the country is closely cultivated.

The party was divided into five topographical survey camps and one traverse camp as below under the following Provincial Officers:—

No. 1, Mr. E. J. Biggie, sheets $55\frac{G}{5, 9, 13}$ and south halves of $53\frac{F}{12, 16}$ and $53\frac{J}{4}$.

No. 2, Mr. A. C. Bose (Traversing) in sheets $53\frac{K}{1, 2, 3, 4, 5, 6, 7, 8, 10, 11, 12, 15}$.

No. 3, Mr. P. A. T. Kenny, sheets 53 $\frac{B}{13}$, $\frac{E}{4}$, $\frac{F}{1}$, $\frac{G}{6, 10}$.

No. 4, Mr. A. J. A. Drake, sheets 53 $\frac{G}{11, 12, 14, 15, 16}$.

No. 5, Mr. F. H. Grant, sheets 53 $\frac{F}{11, 15}$, $\frac{J}{3}$ and north halves of 53 $\frac{F}{12, 16}$, $\frac{J}{4}$.

No. 6, Mr. F. J. Grice, sheets 53 $\frac{G}{2, 3, 4, 7, 8}$.

The work consisted chiefly of revision survey with a small area of resurvey, both on the scale of 1 inch to one mile.

Owing to the large errors found last field season in the position of trijunction pillars and between common boundaries. and to the difficulty experienced in recess in obtaining correct photo-enlargements of irregularly distorted field originals, no blue prints of the old 1-inch survey sheets were used in revision survey this season. Instead of using these unsatisfactory blue prints, new sheets for each plane-table section were prepared in the following manner. During recess the rectangular co-ordinates of all graticule corners, referred to the origin of survey that had been adopted for the traverse data of each district, were computed. Rectangular co-ordinates 100 chains apart, in terms of each origin, were then projected, and the graticule laid down by rectangular co-ordinates was checked against the spherical co-ordinates as given in the Auxiliary Tables. All available traverse data and triangulation was then plotted. Trace prints of the old one-inch sheets were obtained from Calcutta, and the detail transferred piecemeal by adjusting the newly plotted traverse and triangulation points to the old ; boards were then inked up in blue.

The result was most satisfactory. There were no irregularities of graticule to contend with, the points were correctly plotted and hence gave the surveyor confidence, and as all necessary detail such as limits of cultivation, obsolete symbols etc., had been omitted in transferring, there was nothing. to confuse the plane-tabler. The average chaining error in the old "blue prints" system had been from 6 to 8 chains between trijunction pillars while on the system adopted this year it was found to be 2 chains.

The outturn of topography of the party for the season is as follows :—

1-inch Revision Survey 6,117·141 square miles.

1-inch Resurvey 84·46 square miles.

Total 6,201·601 square miles.

The area surveyed comprised sheets 53 $\frac{B}{13}$, $\frac{E}{4}$, $\frac{F}{1, 11, 12, 15, 16}$, $\frac{G}{2 \text{ to } 16}$, $\frac{J}{3 \text{ and } 4}$, or a total of 24 sheets. The survey of sheets 53 $\frac{K}{1, 2, 3, 4, 5, 6}$ formed part of the original programme but owing to slow progress in the difficult Siwālik Hills country, and to transfers of surveyors to the Simla Survey Detachment, these sheets were abandoned.

In computing the cost-rates and outturns the small area of Resurvey has been included in Revision Survey.

The cost-rate per square mile for Resurvey and Revision Survey combined was Rs. 10·46 per square mile.

The average outturn per man per month was 28·6 square miles, or 1·14 square miles per working day per man.

Triangulation.—No triangulation was done by the party during the year.

Traversing.—The traversing of Bijnor district was completed during the year. This district with the exception of Chāndpur, Bāshta and Nagīna parganas had not been previously traversed. The old 1-inch maps of Bijnor were prepared from congregated village plans, and are consequently inaccurate. The traversing was necessary therefore for purposes of revision survey next season if possible, or more probably, to supply points for new survey.

The section in charge of Mr. A. C. Bose was composed of 8 traversers and 2 computers.

In the open cultivated areas owing to pressure of time and questions of expense it was not found possible to pick up all trijunction pillars ; a large number however were picked up. In the forest areas it was only possible to

traverse along roads and natural features, stations being made near large trees which were marked and offsets taken to them.

The outturn was 1,373·7 linear miles with 4,777 stations and covering 1,333 square miles of Bijnor district and lying in sheets 53 $\frac{K}{1, 2, 3, 4, 5, 6, 7, 8, 10, 11, 12, 15}$, at a cost of Rs. 14·7 per square mile.

The rate of traversing was 32·7 linear miles per man per month or 31·7 square miles per man per month or roughly 1 square mile per man per diem.

Recess duties.—The fair mapping, comprising 24 one-inch sheets and 11 village boundary editions, will be completed before the end of the recess, and with the exception of 3 village boundary edition sheets, will be submitted by November 1914. These latter sheets cannot for the present be fully completed, as the local authorities are unable to supply us with the data necessary. Up to October 1st, 1914, the following one-inch sheets have been submitted for publication :—53 $\frac{G}{2, 3, 4, 6, 7, 8, 9, 10, 11, 12, 14, 15, 16}$. The following sheets are practically complete, but owing to 3 Provincial Officers of the party having proceeded on Field Service, are awaiting examination, and will be submitted by November :— 53 $\frac{B}{13}$, $\frac{E}{4}$, $\frac{F}{1, 11, 12, 15, 16}$, $\frac{G}{5, 13,}$, $\frac{J}{3, 4}$.

The village boundary editions submitted or to be submitted during recess include 53 $\frac{H}{12, 16}$, 54 $\frac{M}{2, 6, 10, 11, 12, 16}$. The 3 sheets which cannot be submitted are 53 $\frac{L}{4, 8, 12}$.

The party was divided into six sections and employed as follows :—

Mr. E. J. Biggie and 8 surveyors and draftsmen, fair mapping 53 $\frac{G}{2, 5, 9, 13, 14}$, 53 $\frac{J}{4}$.

Mr. P. A. T. Kenny and 7 surveyors and draftsmen, fair mapping 53 $\frac{E}{4}$, $\frac{F}{1}$, $\frac{G}{6, 10}$.

Mr. A. J. A. Drake and 8 surveyors and draftsmen, fair mapping 53 $\frac{B}{13}$, $\frac{G}{11, 12, 15, 16}$.

Mr. F. H. Grant, 2 Upper Subordinate Service Officers and 7 surveyors and draftsmen, fair mapping 53 $\frac{F}{12, 15, 16}$, $\frac{J}{3}$.

Mr. F. J. Grice and 8 surveyors and draftsmen, fair mapping 53 $\frac{F}{11}$, $\frac{G}{1, 3, 4, 7, 8}$.

On September 1st, Mr. P. A. T. Kenny was transferred to No. 1 Party and the completion of his sheets was handed over to other officers.

On September 15th, Messrs. Drake, Grant, and Grice proceeded on Field Service and their work was after some delay handed over to Messrs. Freeman and Hughes and to Mr. L. Williams; the latter's services were very kindly lent by the Superintendent of the Trigonometrical Survey to assist in examination of maps.

Mr. Bose, 3 computers and 1 plotter completed the computation of the traversing and the rectangular co-ordinates of graticules for next season's work; also various other computations for next season ; prepared village boundary editions and plotted plane-tables for use in the field.

The recess office opened in Mussoorie on 27th April. Owing to transfers to other parties and to the large number of village names to be typed, a special set of typers, working overtime and on all holidays, had to be formed and trained in order to get through the work. Great difficulties were experienced with the dabbers during the monsoon as no satisfactory composition could be secured. All formulæ tried produced dabbers that rapidly become soft, and during the wettest season, the old rubber rollers had to be utilized.

The drawing on the whole is good but the typing is inferior.

For the best class of work a programme of 24 sheets, if it contains any considerable number of hill sheets, is too heavy for a field party. The preparation of village boundary editions for plains sheets adds to the burden. For really creditable work, with the average personnel of a field party, a maximum of 20 sheets would be better, giving a fair compromise between quantity and quality.

The cost-rate of the fair mapping is Rs. 4·7 per square mile.

No. 4 PARTY.

BY CAPTAIN L. C. THUILLIER, I.A.

PERSONNEL.

Imperial Officers.

Captain L. C. Thuillier, I. A., in charge up to 31st October 1913, and from 16th September 1914.

Captain R. Foster, I. A., attached from 24th to 31st October 1913 and from 16th September 1914 and in charge from 1st November 1913 to 15th September 1914.

Provincial Officers.

Mr. G. J. S. Rae.
„ H. W. Biggie, up to 30th August 1914.
„ J. C. C. Lears.
„ G. E. R. Cooper.
„ Duni Chand Puri.

Upper Subordinate Service.

Mr. Mohammad Husain Khan.

Lower Subordinate Service.

46 Surveyors, etc.

The field head-quarters of the party opened at Fyzābād on 20th October 1913 and closed on 6th April 1914; recess office opened at Mussoorie on 16th April.

The area surveyed comprised parts of districts Shāhjahānpur, Hardoī, Kherī, Bahraich, Gondā, Bastī and Fyzābād of the United Provinces.

Sanction was obtained from the Nepāl Durbar to survey portions of Nepāl falling in sheets which also contained portions of British territory, so as to complete all sheets up to margins. Sanction, however, was obtained too late to complete all sheets within the field season.

Sheets 62 $\frac{D}{15}$ and $\frac{H}{3 \text{ and } 4}$ and 63 $\frac{E}{9}$ and $\frac{I}{15}$ were completed and 63 $\frac{I}{6 \text{ and } 10}$ nearly so. A broad strip of Nepāl territory was however surveyed on all the remaining sheets, *viz.*, 62 $\frac{D}{10 \text{ and } 14}$ and $\frac{H}{12}$ and 63 $\frac{I}{14}$ which could not be surveyed owing to the formation of the hills without the surveyor making a long detour into Nepāl which was not considered advisable.

The British portion of the country surveyed consisted of flat plains, interspersed with numerous orchards and thickly populated. Along the northern border of the province is a belt of thick jungle, chiefly *sal*. The portion of Nepāl falling in 62 D and H comprises large areas of cultivation and jungle intermixed, the whole intersected by many large streams. The portion in 63 I on the other hand consists of hills rising abruptly 2,000 feet from the plains and the main streams flowing through precipitous gorges on almost level beds. The hills are in many places covered with thick jungle; pine trees being found on the higher and more northern slopes.

The chief rivers falling in the areas are the Sārdā, Gogrā or Kauriāla and the Rāptī.

Topography.—The programme of work comprised re-survey on the 1-inch scale of sheets 54 $\frac{M}{15}$, 63 $\frac{I}{1, 2, 3, 4, 5, 6, 7, 8, 10, 11, 12, 14, 15, 16,}$ and $\frac{J}{4, 5, 9, \text{ and } 13,}$ and the Nepāl portions of 62 $\frac{D}{10, 14, \text{ and } 15,}$ and $\frac{H}{3, 8, \text{ and } 12,}$ and 63 $\frac{E}{9}$ and supplementary survey on the 1-inch scale of sheets 54 $\frac{M}{15}$, 62 $\frac{D}{10, 11, 12, 14, 15, 16,}$ $\frac{H}{3, 4, 7, 8, \text{ and } 12,}$ 63 $\frac{A}{1}$ and $\frac{E}{11}$.

Sheets 63 $\frac{A}{1}$ and $\frac{E}{11}$ were arrears from previous season, 54 $\frac{M}{15}$ was transferred from the programme of No. 3 Party and the Nepāl portion of 63$\frac{E}{9}$ was only surveyed this season, the British portion of the sheet having been completed in the preceding season.

The hilly portions of 63 $\frac{I}{6 \text{ and } 10}$ could not be contoured owing to there being no triangulator available. The hills were therefore represented by form lines only.

Surveyors did not commence actual survey work till the 1st of November owing to a large amount of fair mapping of the previous season which it was not found possible to complete before the party left for the field.

The work was distributed among 4 camps under Messrs. G. J. S. Rae, H. W. Biggie, J. C. C. Lears and G. E. R. Cooper. Mr. Duni Chand Puri and three surveyors working in the detached sheets 54 $\frac{M}{15}$ and 63 $\frac{A}{1}$ were under the direct supervision of the officer in charge.

In the month of February 1914 surveyors Jit Singh, Imdad Husain and Raghubar Dayal were transferred to Simla Survey Detachment. Surveyor

Narayan Datta fell sick with a severe attack of pleurisy shortly after the field season commenced and surveyor Munshi Ram died of cholera at the beginning of recess.

The average outturn per man per month was 41·3 for supplementary survey and 26·1 for re-survey.

Cost-rates.—These are as under :—

Detail survey 1-inch scale 7,040 square miles at Rs. 9·2 per square mile.

Traversing.—196 linear miles of traverses were run this season, chiefly in 63 $\frac{\text{H}}{\text{3 and 8}}$ for the surveyors taking up the work in Nepāl, but a portion at the beginning of the season consisted of supplementary traverses to provide surveyors with extra points where necessary.

Recess duties.—During recess the whole 31 sheets surveyed were mapped on the 1½-inch scale. Twenty of these have been completed and sent to the Superintendent, Northern Circle, and the remainder should be sent in by the end of recess.

The Nepāl portion of 63 $\frac{\text{E}}{9}$ (the British portion of which had been drawn the previous season) was added to the sheet, and the completed sheet again submitted.

The compilation of village boundary editions of 1-inch sheets was continued throughout the year by a small staff. The following sheets have been submitted this year, bringing the work up to date :—63 $\frac{\text{A}}{\text{3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, and 16}}$ and $\frac{\text{E}}{\text{1, 3, 4, 5, 6, 7, and 8}}$.

The health of the party was good, except at the end of the season amongst the members of the party working in the Nepāl jungles, many of whom suffered from attacks of malarial fever.

Inspections.—The Superintendent, Northern Circle, inspected the party during the field season in February, and visited the party during recess. The Surveyor General inspected the party during the field season in March, and recess office in September.

No. 20 PARTY (CANTONMENT).

BY MR. A. EWING.

During the year under report, the party was employed on the survey of *Guna, Kamptee* and *Rājkot* cantonments on scale 16 inches to a mile, with their bazaars on scale 64 inches to a mile, and Sītābaldi Fort on scale 36 inches to a mile. The triangulation and traversing of Meerut, and the triangulation of Sanāwar, and Dehra Dūn have been completed in advance for season 1914-15. The contouring of Saugor was completed during the months of July, August and September; and traverse work was started in Dehra Dūn in August. Forty fair maps were sent for publication.

PERSONNEL.

Provincial Officers.

Mr. A. Ewing in charge.

" C. S. Littlewood, to 20th September 1914.

Upper Subordinate Service.

Mr. Dharmu.

Lower Subordinate Service.

24 Surveyors, etc.

The field season commenced in Guna on 1st October 1913, and closed, for detail survey, on 20th June 1914; but the triangulation and traversing continued till the end of the season.

Owing to the men working in cantonments, where the sanitary arrangements, and treatment of sick men in hospital are good, there was not much sickness in the party. A surveyor and a pupil surveyor were ill with gall stones and small-pox; but the health of the khalasis was good.

Topography.—As this party was formed at the end of the previous year, there was no triangulation, and traversing done in advance, and the detail

surveyors were delayed till the triangulation and traversing in Guna was completed and computed. After the survey of Guna was commenced, Mr. C. S. Littlewood, and Gokul Chand, surveyor, were sent to Kamptee in November 1913 to start the traversing and have traverse data ready; while Mr. A. Ewing remained in charge of the surveyors in Guna, and trained three pupil surveyors. In January the survey of Guna was finished, and the surveyors were sent to Kamptee and placed under Mr. C. S. Littlewood, who continued in charge of the survey of Kamptee and Sītābaldī Fort till 20th June. Gokul Chand, after completing the traversing of Kamptee, was sent to Rājkot to do the triangulation, traversing, and survey of that cantonment.

The accuracy of detail survey was thoroughly tested by Mr. A. Ewing, who ran 25·9 linear miles of test lines in nearly every field sheet, and also by Mr. C. S. Littlewood by 12·0 linear miles of *partal* in Kamptee and Sītābaldī Fort.

The following table gives the outturn and cost of the survey of Guna, Kamptee, and Rājkot cantonments, and Sītābaldī Fort:—

	Acres.	Rs
Scale 16 inches to one mile	13,019	16,905
„ 36 „ „ „ „	175	800
„ 64 „ „ „ „	528	4,692

The total cost of Rs. 22,397 for detail survey, is rather high, and is due to there being only 4 experienced surveyors in the party; but next field season there will be 8 pupil surveyors, now under training, who will be able to do nearly as much as trained men, and this will reduce cost-rates.

Triangulation.—Sufficient number of stations and intersected points were fixed in Rājkot, Meerut, Sītābaldī Fort, Sanāwar, and Dehra Dūn for the connection of theodolite traverse stations. Mr. A. Ewing, Mr. Dharmu, and Gokul Chand were employed on the triangulation. The average angular and linear errors are slightly higher than in the triangulation done by topographical parties; but it is quite good enough for what it is intended, *viz.*, reducing errors in chaining of the traverse lines on which the detail survey is based. 104·5 square miles of triangulation was done at a cost of Rs. 2,344-0-0.

Traversing.—During the year the traversing of Guna, Kamptee, Rājkot, Sītābaldī Fort, and Meerut was completed, and the traversing of Dehra Dūn is now in hand. Messrs. C. S. Littlewood and Dharmu, and Gokul Chand, Muhammad Hanif, Niaz Ahmad Khan, surveyors, Debi Datta, computer, and Arthur E. A. Francis, pupil surveyor, were employed on traversing. Gokul Chand traversed 158 linear miles and the others did 99 linear miles. As Mr. Dharmu and Gokul Chand are the only men who thoroughly understand traversing and observing for azimuths, I have had to train 3 surveyors and a computer for this work, in anticipation of employing one or two more traversers as the work of the party increases. The azimuths observed, angular work and chaining are very good. 9 azimuths, 2,407 angles, and 257 linear miles of traversing was done at a cost of Rs. 9,593-0-0.

Levelling.—Some levelling was carried out in Guna, Kamptee, and Meerut, and in addition to the bench-marks given by the Great Trigonometrical Survey in these cantonments, 18 more bench-marks were observed. No levelling was required in Rājkot and Sītābaldī Fort as there were Great Trigonometrical bench-marks. The cost of levelling is Rs. 220-0-0.

Recess duties—(*a*) *Fair mapping.*—Forty fair maps (including 6 out-line sheets of Saugor) were sent for publication, and 36 sheets were drawn during the year. Three sheets are now in hand, and eight are now remaining to be drawn. These eleven sheets will be completed and sent to press by the end of December 1914. The fair mapping was done under the supervision of Mr. A. Ewing, who examined all the sheets before sending them for publication.

The cost of fair mapping 36 sheets is Rs. 8,540-0-0. There are no arrears of fair mapping.

(*b*) *Other recess duties.*—During the months of July, August and September the training of pupil surveyors has been systematically carried out. There are now eight pupil surveyors who are capable of doing independent surveying,

and three of them have been employed on drawing fair maps. All of the pupil surveyors, before being recommended for appointment in the department, have been practising drawing at their own expense for two or three months. No one has been recommended who has not shown promise of being a good draftsman. All traverse stations have now been permanently marked by mark-stones on which either a circle and a dot, or a cross have been cut. It is absolutely necessary to have traverse stations thus marked if corrections or revisions of cantonment plans have to be made with any accuracy.

Programme for season 1914-15.—Survey of Meerut, Sahāranpur Remount Depot, Bābūgarh Stud Farm, Dehra Dūn and Landour; also the triangulation and traversing of Peshāwar and Jullundur for season 1915-16.

RIVERAIN DETACHMENT.

BY MR. MAYA DAS PURI, RAI SAHIB.

PERSONNEL.

Provincial Officers.

Mr. Maya Das Puri, Rai Sahib, in charge.

Upper Subordinate Service.

Mr. Chuni Lal Kapur.
„ Mahindar Singh, from the 11th August 1914.

Lower Subordinate Service.

79 Surveyors, traversers, etc.

SETTLEMENT STAFF.

1 *Naib Tahsildār.*
10 *Kanungos.*
1 Sub-Assistant Surgeon, to 13th August 1914.

The field operations were commenced on the 1st October 1913, and closed during the middle of July 1914. Two traversers were, however, continuously employed during recess for revising the urgent part of the Kāngra work.

The office was shifted to Gujrāt on the 20th October 1913. It was again removed from there to Dharmsāla on the 7th May 1914, where it was allowed to recess during the summer as a special case.

The detachment continued the work of traversing and laying down base lines. 2,435 linear and 485 square miles of minor traverse were run. 10,471 theodolite stations were fixed in the area, under water action, of the rivers Sutlej, Rāvi, Chenāb, and Jhelum, in districts Jullundur, Lahore, Siālkot, and Gujrāt. 726 corners of 242 squares were demarcated in 401 square miles with permanent mark-stones on both banks of the Rāvi (district Lahore), and Jhelum (districts Gujrāt, Jhelum, and Shāhpur) to serve as bases for the future survey and demarcation of boundaries in the bed of these rivers. 2,151 plotted and 506 boundary "*masāvis*" (settlement mapping sheets) of 309 villages were completed, and 33 four-inch sheets and 4 one-inch indexes were traced; and supplied in time to the Settlement Officers of Jullundur, Lahore, Siālkot, and Gujrāt. Besides these 227 miscellaneous traces were prepared, and all the traversed stations marked during the season were plotted on the four-inch sheets. Five four-inch riverain boundary sheets were finally completed.

The details of the above are shown in the following three tables :—

(1) OUTDOOR WORK.

NAMES OF RIVERS, DISTRICTS, AND SCALES.	Straight length in miles.	MINOR TRAVERSES FOR DETAIL SURVEY.				BASE LINES.			REMARKS.
		Number of square miles.	Linear miles.	Number of theodolite stations.	Number of villages.	Number of corners.	Number of squares.	Area in square miles.	
Jhelum River.									
Gujrāt and Jhelum, scale 220 feet = 1 inch.	44	88	689	2,685	96	300	100	131	
Jhelum River, Shāhpur, scale 220 feet = 1 inch.	4	...	21	63	...	45	15	12	
Rāvi River.									
Lahore, scale 220 feet = 1 inch .	65	306	1,233	5,749	115	381	127	258	
Sutlej River.									
Jullundur, scale 200 and 330 feet = 1 inch.	42	82	433	1,719	81	...	...	...	
Chenāb River.									
Siālkot, scale 220 feet = 1 inch .	8	9	59	255	17	...	..	...	
TOTAL .	163	485	2,435	10,471	309	726	242	401	

(2) OFFICE WORK DONE FOR THE CADASTRAL SURVEYS OF RIVERAIN ESTATES.

Name of river.	Name of district.	Scale of *masāvis*.	Number of plotted *masāvis* showing traversed points.	Number of compiled *masāvis* showing riverain boundaries.	Number of sheets traced for the use of Settlement Officers on scale 4 inches = one mile.	Number of 4-inch sheets on which new work was plotted.
Sutlej .	Jullundur .	330 feet and 200 feet = 1 inch.	432	131	6	7
Rāvi . .	Lahore	220 feet = 1 „	1,048	256	14	15
Chenāb .	Siālkot .	220 „ = 1 „	71	...	3	2
Jhelum .	Gujrāt and Jhelum.	220 „ = 1 „	600	119	10	9
		TOTAL .	2,151	506	33	33

Besides these 4 one-inch indexes and 227 miscellaneous traces were prepared during the year.

(3) OFFICE WORK DONE FOR THE FOUR-INCH COMPILATION OF RIVERAIN BOUNDARIES.

Names of rivers.	Names of the series.	Number of sheets finally examined.
Rāvi	Lahore	2
Jhelum	Gujrāt / Jhelum . . .	3
	TOTAL .	5

The Khushāb Thal.—(Sandy area) survey was carried in continuation of the last year's work. 103 linear and 200 square miles were traversed, and 180 theodolite stations laid out. 63 dressed stones and 182 iron tubes were embedded over the whole of *Thal* in suitable places to facilitate future survey and demarcation. 83 plotted and 5 boundary *masāvis*, and 16 four-inch traces showing compiled boundaries, were supplied to the Settlement Officer, Shāhpur.

Kāngra Special Survey.—After settling the preliminary details with the Settlement authorities the Kāngra special survey was started on the 15th December 1913 in the Pālampur tahsil, and was temporarily stopped during the middle of July 1914.

Ten Settlement *Kānungos* and one *Nāib Tahsildār* were deputed during February and March 1914, and several new hands were entertained.

The estimates for this work were calculated on the basis of the experimental survey, where at an average 22 stations per square mile had been laid out, but this year the demand of the Settlement authorities was far greater than that of the previous year, and so the average comes to 42 points per square mile. Besides this the scale of the survey was doubled by the Settlement authorities almost everywhere in the Pālampur tahsil on account of which several *tikās* had to be plotted twice. Moreover the ground under survey this season was more difficult than that of the previous season, and a good deal of time was spent in training the new men. Constant bad weather was also a serious hindrance to the progress of the work. For all these reasons the work was considerably increased, and was completed in time in the Pālampur tahsil with great difficulty. The cost per theodolite station this year works

out to Rupees 2·8 as compared with Rupees 3·1 per station of that of the previous season.

As desired by the Settlement Officer, Kāngra, the boundaries falling in thick forests and along inaccessible snowy ranges were left out in 145 square miles of the Pālampur tahsil with a view to save jungle clearing and reduce the cost of the work. In a few such cases the village boundaries were enlarged from the original survey sheets, and are being tried on the ground by the *patwaris;* and if found satisfactory the procedure will be extended to the remaining such area.

The work was based on the old No. 18 Party (Himālaya)'s triangulation. In all 3,396 linear and 400 square miles were traversed and triangulated, 16,827 stations fixed with theodolite in 1,433 *tikās* (sub-villages) of the Pālampur and Kāngra tahsils, and 16 square miles of boundaries enlarged. 94 boundary *masāvis* of 10 *tikās*, and 4,934 plotted *masāvis* of 952 *tikās* were supplied to the Settlement Officer, Kāngra. 947 plotted *masāvis* of 272 *tikās* and 156 boundary *masāvis* of 20 *tikās* are ready to be despatched, and 31 four-inch sheets were plotted and completed.

Gujrāt Rectangular Survey.—At the end of January 1914 intimation was received from the Settlement Officer, Gujrāt, to start the 25-acre rectangular survey in the tract commanded by the upper Jhelum canal along the Chenāb river in the districts of Gujrāt and Shāhpur. The detachment was required only to form blocks subsequently to be split up into 25-acre rectangles by the Settlement Department. The work was commenced on the 21st February 1914, and finished on the 12th June 1914.

First of all the area was theoretically divided into 25-acre rectangles on the two-inch sheets. The blocks were cut on the ground along suitable lines of the rectangles. The northern and southern sides were demarcated at every 1,100 feet, and the eastern and western ones at every 990 feet. *Burjis* (dressed stones) were embedded on the corners of 100 acres, and 2 bricks vertically placed over each other were put up over those of 25 acres, and were numbered from left to right. Three traversers, two computers, and one Upper Subordinate officer were employed on this work. It was based on the old No. 1 Party (Punjab)'s traverse values, and no use was made of the latest riverain work. 1,605 corners of the rectangles forming 38 blocks were demarcated covering 9,186 25-acre rectangles, or 359 square miles. Nearly the whole of the work was checked with a theodolite traverse. 663 linear miles were traversed, and 1,605 theodolite stations were fixed.

Nature of country.—The country under survey in the riverain and the Khushāb *Thal* (sandy area) resembled that of the previous season. The Kāngra district consisted for the most part of precipitous mountain ranges from 3,000 to 14,000 feet high above the sea level, intersected with deep valleys, covered with jungle, and in parts well cultivated. Portions over 8,000 feet were covered with snow generally all the year round, and contained only scattered bits of cultivation here and there. The Gujrāt-Shāhpur tract was flat, open, cultivated, and well wooded.

Health.—The health of the detachment was on the whole fairly good. There were several cases of malaria early during the field season. Most of the hands suffered from fever, dysentery, and dyspepsia while at Dharmsāla. One traverser, one draftsman, and four *khalāsis* died from pneumonia and typhoid fever: and some men had to go on leave on account of ill health.

The Kāngra survey was connected with Gumber G. T. S., 18 secondary and intersected points of the G. T. Survey, and 80 triangulated stations of the old No. 18 Party (Himālaya). The Gujrāt-Shāhpur rectangular survey was connected with three Tower Stations.

The average errors in the different classes of work were as follows :—

1. *The Riverain Survey*:—

(*a*) Minor traverses—

Angular error 9·4″ per station.

Linear error 0·91 link, per 10 chains.

(*b*) Base lines—

Error per corner 1·24 links in direct distance when compared with its theoretical value.

2. *The Khushāb Thal Survey*:—

Minor traverses—

Angular error 4·9″ per station.

Linear error ·89 link per 10 chains.

3. *The Kāngra Special Survey*:—

Minor traverses—

Angular error 11·4″ per station.

Linear error 1·7 links per 10 chains.

4. *The Gujrāt-Shāhpur Rectangular Survey*:—

Angular error 4·4″ per station.

Linear error 1·2 links per 10 chains.

The total expenditure of the detachment from the 1st October 1913 to 30th September 1914 including the pay of temporary *khalāsis*, was Rs. 87,935 as detailed below:—

	Rs.
1. The Riverain Survey	32,375
2. The Khushāb Thal Survey	4,592
3. The Kāngra Special Survey	46,918
4. The Gujrāt-Shāhpur Rectangular Survey	4,050

The detachment was inspected by the Superintendent, Northern Circle, early in November 1913.

SIMLA SURVEY DETACHMENT.

BY MR. C. E. C. FRENCH.

PERSONNEL.

Provincial Officer.

Mr. C. E. C. French in charge.

Upper Subordinate Service.

Mr. Paras Ram.

Lower Subordinate Service.

14 Surveyors, etc.

This detachment was created on the 11th October 1913 with the object of preparing a new map of Simla. Mr. French, on transfer from No. 4 Party, was put in charge and proceeded to Simla early in November 1913.

Field operations:—

(*a*) The area dealt with included the country lying within the Municipal boundary of Simla; 8·4 square miles in extent, covered with forest and heavy detail.

(*b*) The field surveys are being done on a scale of 125 feet to 1 inch.

Procedure as follows:—

(*i*) Sheets of the Simla Estate Boundary map of 1900-04, 109 in number, on a scale of 50 feet to 1 inch, have been reduced in blue and the topographical details completed by means of the plane-table.

(*ii*) The blank sheets lying on the outer limits of the station, have had a number of traverse points fixed in them for the plane-tabler. Up to the present 23·8 linear miles of traverse line have been run.

(*iii*) The contouring will be done by means of traverse heights, of which over 6,000 are available, supplemented by 31 bench-marks furnished recently by No. 17 Party.

Up to the present time, 50 sheets or 2,418 acres have been surveyed; this is being continued but with a much reduced staff, the reason being that of late the requirement of the Simla Improvement Committee have reduced the preparation of the general Simla map to a matter of secondary consideration.

The detachment has now in hand the following:—

(*a*) Plans of the following bāzār blocks on a scale of 20 feet to 1 inch,

showing interior details, ownerships, and in places, longitudinal sections and elevations:—

Bara Simla.	Sanjaoli.	Boileauganj.
Chota Simla.	Mashobra.	Bharari.
Kasumpti.	Kaithu.	Nābha House Estate.

(*b*) Survey on the scale of 8 inches to 1 mile, of about 2 square miles of country (lying as an irregular strip between Tarā Devī and Summer Hill) fully contoured, showing all boundaries, classification of forest jungle, grass lands, building sites. This is likely to be largely extended in the near future.

(*c*) Survey on a scale of 4 inches to 1 mile of the forests in Koti State, estimated at 3·9 square miles.

Recently some special pieces of work have been completed to meet the requirements of the Simla Improvement Committee; as below:—

(*a*) Several large scale plans with sectional drawings of portions of the Bara Bazar, Simla.

(*b*) A plan of Mashobra bazar and environs on a scale of 20 feet to 1 inch.

(*c*) A series of reduced level heights at 20-foot intervals, on lines marked on the map and laid out on the ground; total length 4,520 feet. These were supplied with plans.

(*d*) Traces, with areas of some 85 acres of land surveyed in connection with a proposed colonisation scheme.

(*e*) Several traces prepared from the field sheets of the present survey to illustrate road projects and drainage schemes.

(*f*) Enfacement of all available bench-marks and traverse heights on traces supplied by the Executive Engineer.

The drawing of the Simla map has not been commenced yet, the detachment being employed on the details above.

The field sheets of the Simla Survey which have been completed, area 2,418 acres, have been tested by 168 fixings and 63 chains of check line.

For the purpose of accounts the Simla Survey Detachment formed part of the office of the Superintendent, Northern Circle, and the total expenditure of the detachment for the year is Rs. 29,433.

The Superintendent, Northern Circle, inspected the detachment on the 18th April and 14th July 1914; and the Surveyor General on the 1st July.

SOUTHERN CIRCLE.

(*Vide* Index Maps 2 and 5.)

Summary.—The Southern Circle was under the superintendence of Lieutenant-Colonel F. W. Pirrie, I.A., up to the 7th September 1914 and under Colonel T. F. B. Renny-Tailyour, C.S.I., R.E., from the 8th September 1914.

The Circle consisted of Nos. 5, 6, 7 and 8 Parties, No. 4 Drawing Office and a Training Section.

An area of 15,844 square miles was surveyed consisting of:—

3,086 square miles of	½-inch survey.
10,037 " " "	1-inch survey.
637 " " "	1-inch revision survey.
1,393 " " "	1-inch supplementary survey.
343 " " "	1½-inch survey.
348 " " "	2-inch survey.

The following work was undertaken in the Photo-Zinco Section of No. 4 Drawing Office:—

Reproductions to full scale	9
Enlargements	156
Reductions	89
Sheets vandyked	107
Copies printed	4,450

Note by Lieutenant-Colonel F. W. Pirrie, I.A.

1. The charts and 1-inch revenue reductions, supplied by the Director, Madras Revenue Survey, were extensively used and justify the expenditure incurred on their preparation, they were of considerable assistance in the topographical survey, and their usefulness in future will probably be still greater as arrangements have been made for the omission of much detail usually shown on cadastral maps, which takes time and labour to compile, and for the inclusion of such information on them likely to be of use from a topographical point of view.

2. The cost of new triangulation or traversing in parts of the low lying inclosed country near Madras and along the eastern sea coast would be excessive, so it is intended to utilize the village trijunction pillars, which are also revenue traverse stations, as fixed points, supplemented by a few height traverses where absolutely necessary.

3. In parts of India where much old triangulation and traversing and many old maps of varied quality exist it is always a problem how far these materials can be or should be utilized to assist modern revision or supplementary surveys. The following procedure will probably be found suitable in the more populated areas of the Southern Circle and is very similar to what is being done by No. 7 Party:—

The officers detailed for triangulation should have sufficient experience to know from the local nature of the country and data available whether it is more economical to triangulate or to carry out theodolite height traverses. In special circumstances it may be advisable to do secondary levelling where very accurate heights are necessary or there are wide or inconsistent differences between existing triangulation heights and those obtained by spirit levelling of precision.

If 1-inch detail surveys are contemplated and there is much old data to be examined, the ½-inch scale should be selected for the field triangulation and traverse chart. Different charts should be prepared for traverses computed with reference to different origins.

The rectangular co-ordinates of the corners of the ½-inch sheets concerned should be computed after applying the correction of —2′—27″·18 or whatever is necessary to reduce the position of the origin to its modern equivalent. The blank ½-inch charts should be ruled with ½-inch squares and numbered suitably along the margins so as to bring the work to be done in the most suitable position. The corners of the particular ½-inch sheet should then be plotted according to their rectangular co-ordinates and the traverse stations straight from the original traverse volumes. Village trijunctions are usually traverse stations and should be shown by small squares, other traverse stations are not usually permanently marked but if known to be permanently marked in the particular locality should be shown by small circles. The graticule lines should then be inked up and scales of latitude and longitude prepared and any existing triangulated points plotted. The whole of the above should be shown by firm black lines.

The most suitable existing map on the 1-inch or smaller scale should be selected and printed on the ½-inch scale on tracing paper in black. The ½-inch print on tracing paper of the map should then be fitted on to a vandyke print of the triangulation and traverse chart by means of the fixed points so as to give the best mean position for the map on the chart. The corners of the graticule can then be marked on the map in black and a combined print showing triangulation and traversing in burnt sienna and detail in blue should then be prepared. It may sometimes be necessary to cut up the black print on tracing paper and paste on the pieces after adjustment on the triangulation and village trijunctions and in order to incorporate reductions of larger scale forest maps, and, if this is the case, it may be necessary to re-vandyke. The spirit levelling heights should then be plotted according to their descriptions on the spirit levelling charts in some distinctive colour.

The method of using these preliminary charts would be to ink up whatever stations were found and used and also to ink up selected village trijunctions after identification and connection. Selected and important level bench-marks should be connected with the triangulation so as to work out subsequently a mean correction to reduce the triangulation heights to spirit level terms.

If the country is systematically gone over in this way the maximum possible of old triangulation and traversing will be used and it will be evident where further triangulation or height traversing should be done.

In order to fix more heights for topographical purposes height traverses, carried out with theodolite double chaining and the new height staff, will usually be found suitable and the heights of village trijunctions and natural prominent objects can be fixed by intersection from three or more traverse stations.

4. In order to cope with the rush of work in the Photo-Zinco Section of No. 4 Drawing Office towards the close of the field season and at the beginning of recess it was necessary to employ all the apparatus available and individuals of varied capabilities on work within their powers, and in order to carry out these principles the following arrangements were made :—

A coned adaptor was made to take the Zeiss lens and reversing prism and fitted outside one of the windows of the studio. The screen was placed outside and the studio itself was used as a camera as at Dehra Dūn. The image was produced on a ground glass of the same thickness, size and weight as the glass used for the negative. Accurate enlargements to the 1½-inch scale of full 1-inch field sheets were easily obtained with this apparatus.

If ⅔ or more of a 1-inch sheet had been surveyed on one plane-table in the field, black traces on tracing paper from the remaining plane-tables falling in the sheet were lightly pasted by the edges on to the large plane-table section and the whole enlarged.

Many sheets, especially where the 1-inch and ½-inch scales of field surveys adjoin, were much cut up into small irregular and fragmentary field sections, and it was found convenient to deal with them differently. In such cases and in all cases where less than ⅔ of a 1-inch sheet had been surveyed on the largest field section in the sheet, each field section was enlarged individually to the 1½-inch scale in black on tracing paper and these enlargements were carefully pasted on lightly by the edges on to a sheet of 150-lb. drawing paper on which a graticule had been drawn with 5 minute divisions. The pasted up 1½-inch sheet was then vandyked to scale in blue ready for the fair draftsman.

These two systems had relative merits and drawbacks. The first method produced the best and sharpest enlargements and the majority of No. 7 Party's sheets were dealt with in this way as well as full plane-tables from other parties. The second system involved the preparation of many small negatives and zincs with increase in cost of materials and labour owing to the blank marginal spaces on coated negatives and grained zinc plates, but it enabled all the smaller cameras and lenses to be employed and comparatively inexperienced operators for if a small negative or zinc is spoilt the cost of preparing others is small.

The depiction produced by the second method was slightly inferior on the 1½-inch vandyke blue prints owing to inequalities on the surface of the paper when in the vandyke printing frame. Oblique rays of light in vandyking also tend to blur the lines, it is possible that these defects might be remedied by placing the printing frame during exposure at the bottom of a square sided tube facing north coated inside with dead black composition or by printing in direct sunlight with a ball and socket arrangement to support the frame and move it with the sun during exposure.

5. Where old 4-inch forest work had to be used for revision survey it was generally dealt with in the following manner:—

Blue reductions to the 1½-inch scale were first prepared and sufficient detail inked up in black by the particular party concerned and pasted in position on to a projected graticule on the 1½-inch scale. On the left margin were pasted on printed lists of triangulated points as well as the record slip, Form P. 79 and any other indexes required. The whole sheet was then reduced from the 1½-inch to the 1-inch scale by photography and from the negative two zincs prepared from one of which the marginal notes, etc. were printed in black and from the other the graticule lines and interior details in blue. This method produced much neater plane-tables than obtained by pasting on slips after other preliminary work had been done.

6. It facilitates work in the Photo-Zinco Section if officers in charge of parties endeavour whenever possible to distribute work in the field in units of 5 minute squares.

7. An exhibition of plane-tables was held in recess 1912-13 and again in 1913-14 and both exhibitions show what excellently drawn plane-tables can be produced in the field by surveyors of the Southern Circle. On both occasions the judging committee awarded marks according to the quality and quantity as set forth by the remarks made by examining officers in the field and the relative difficulties and climatic conditions.

The advantages of Bristol boards over drawing paper mounted on mill board are very evident when the climatic conditions are favourable and the surveyor is an experienced and clean worker.

These exhibitions have served their purpose and it is known what can be accomplished in the way of draftsmanship in the field with care and they will not be continued as an annual institution.

8. There is much difference of opinion as to the relative advantages or disadvantages of drawing paper and 2 ply Bristol boards for fair mapping. The

concensus of opinion is that it is a good deal a matter of individual preference and the tools that best suit the particular draftsman and the kind of sheet to be drawn. Adjustable drawing and swivel pens are more suitable for Bristol board, but there is difficulty in graduating streams with these instruments unless the draftsman is experienced and accustomed to their use. If the draftsman is inexperienced and the sheet is very intricate and difficult and the draftsman is in the habit of using a crow-quill or ordinary drawing nib 210-lb. drawing paper is the best. The final result when the 1⅓-inch fair sheets are reduced by ⅓ on publication is the same if the above principles are borne in mind.

9. The special blue tinted drawing paper was again given a thorough trial in fair mapping, but on the whole. was found inferior to the ordinary 210-lb. white paper in general use.

10. The new special roller pens for roads, foot-paths and boundaries were used and generally approved, but it is difficult to control the amount of printing ink and foot-paths are apt to be more prominent than mule paths.

11. The following things affect the use of a separate type sheet for fair mapping so they are given in this particular note:—

There is no objection to acute intersections of lines that will appear in a different colour on the published map or will be printed in the same colour but from different zinc plates. Great care is taken in preparing the fair maps to avoid acute intersections of lines or lines very close together that will be printed from the same zinc plate and again in examining the fair maps in the Southern Circle Office small erasures and modifications of drawing are frequently made for the same reason.

The use of a separate type sheet in fair mapping which was tried in 1912-13 is not justified by the experience gained as an ordinary method of work as it produces difficulties in examination and tracing and even with great care ornamentation from the outline sheet sometimes falls on typed names from the type sheet on publication. The use of a separate type sheet is sometimes justified if it contains many names and it is necessary for some reason to expedite the completion of the sheet. The use of separate sheets for outline and typed names is entirely justified in the case of large scale surveys of towns and in localities where there is a mass of typed names that must appear without any erasures of detail whatever being made.

No. 5 PARTY (CENTRAL PROVINCES).

BY CAPTAIN E. C. BAKER, R.E.

The work of the party included survey and revision survey in the Hoshangābād, Narsingpur, Chhindwāra, Betūl, Nāgpur and Wardhā districts of the Central Provinces and in the Amraotī district of Berār and triangulation in the Betūl and Nimār districts of the Central Provinces and in the Amraotī and Akola districts of Berār.

PERSONNEL.

Imperial Officers.

Captain E. C. Baker, R.E., in charge.
Lieutenant R. S. Wahab, I.A.
Lieutenant R. L. Almond, R.E., from 12th October 1913 to 12th August 1914.

Provincial Officers.

Mr. J. H. S. Wilson.
„ S. S. McA'Fee Fielding.
„ F. C. Pilcher.
„ Munshi Lal, B.A.
„ C. O. Picard.
„ A. V. Dickson, from 29th November 1913.

Upper Subordinate Service.

Mr. Eknath Battu.
„ Ram Narayan Hastir.

Lower Subordinate Service.

27 Surveyors, etc.

The general nature of the country was varied, it included the steep and wooded hills on the north of the Sātpurā plateau, the undulating and comparatively open plateau, the steep wooded drop off the south edge of the plateau and the flat or undulating cultivated plains below.

The field season opened on the 20th October 1913 and closed on the 27th April 1914. The field head-quarters was at Chhindwāra up to the 6th March 1914 and afterwards at Betūl.

The health of the party was fair. There was a considerable amount of malarial fever, specially among the squads working

in the Chhindwāra *jāgīrs* and two menials died of cholera in the Amraotī district.

Topography.—The work was divided among three camps as follows:—

No. 1 camp under Mr. Wilson consisted of Mr. Dickson and 8 surveyors and carried out the survey of sheets $55\frac{K}{7, 10, 11, 12, 16}$ and of part of sheet $55\frac{K}{6}$.

No. 2 camp under Mr. Fielding consisted of 8 surveyors and carried out the survey of sheets $55\frac{J}{8, 12}$, $55\frac{K}{5, 9}$ and of parts of sheets $55\frac{K}{6, 13}$.

No. 3 camp under Mr. Munshi Lal consisted of Mr. Ram Narayan Hastir and 7 surveyors and carried out the survey of sheets $55\frac{J}{11, 14, 16}$ and of part of sheet $55\frac{J}{15}$.

In addition Lieutenant Almond carried out the survey of parts of sheets $55\frac{J}{15}$, $55\frac{K}{13}$.

The nature of the country surveyed was varied. In degree sheet 55 J from the open cultivated plateau around Chhindwāra town, lying about 2,200 feet above sea level, the hills rose gradually to the main ridge of the Sātpurā range about 3,800 feet above the sea, the hills were thickly wooded. A great deal of degree sheet 55 K was open undulating plateau, the southern slope of the plateau was steep and thickly wooded and the country further south was varied, mostly open and cultivated but with some low hills and forests.

The areas surveyed were 3,505 square miles of 1-inch survey and 637 square miles of 1-inch revision survey of 4-inch forest surveys, making a total outturn of 4,142 square miles. The monthly average outturn per man in the two classes of survey was 27·0 and 48·0 square miles respectively and the cost-rate was Rs. 13·3 and Rs. 9·5 per square mile respectively.

Triangulation.—The triangulation of sheets $55\frac{C}{11, 13, 15}$, $55\frac{G}{1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 13, 14, 15}$ and of part of sheet $55\frac{C}{14}$ was carried out by Lieutenant Wahab and Messrs. Pilcher, Picard and Eknath Battu.

The country triangulated extended from the open Sātpurā plateau westward through the heavily wooded hills and gorges of the Melghāt to the Nimār plains and also southwards off the plateau to the level cultivated plains of Amraotī and Akola.

The area triangulated was 4,796 square miles and the cost-rate was Rs. 8·6 per square mile.

Recess duties.—The fair mapping was divided among three sections as follows:—

No. 1 section under Mr. Wilson, sheets $55\frac{K}{6, 7, 10, 11, 12, 16}$.

No. 2 section under Mr. Fielding, sheets $55\frac{J}{8, 12}$, $55\frac{K}{5, 9, 13}$.

No. 3 section under Mr. Munshi Lal, sheets $55\frac{J}{11, 14, 15, 16}$.

All the fair mapping will be completed and the sheets submitted by the end of the recess season.

The total outturn of fair mapping was 4,142 square miles and the cost-rate was Rs. 5·0 per square mile.

The computation of all the triangulation and the preparation of degree charts 55 J, 55 K will be completed by the end of the recess season.

No. 6 PARTY (BERĀR AND HYDERĀBĀD).

BY CAPTAIN K. W. PYE, R.E.

The work of the party included survey in the Akola and Buldāna districts of Berār and in the Nānder and Parbhani districts of Hyderābād and triangulation in the Aurangābād, Bhīr, Parbhani and Osmānābād districts of Hyderābād and in the Ahmadnagar district of Bombay.

PERSONNEL.

Imperial Officers.

Major H. Wood, R.E., in charge from 4th December 1913 to 23rd February 1914.

PERSONNEL—*contd.*

Imperial Officers—contd.

Captain K. W. Pye, R.E., in charge from 27th April 1914.

Lieutenant C. G. Lewis, R.E., in charge to 3rd December 1913 and from 24th February 1914 to 14th April 1914.

Provincial Officers.

Mr. E. A. Meyer, in charge from 15th April to 26th April 1914.
„ Haji Abdul Rahim, K.B., from 18th June 1914.
„ F. B. Kitchen.
„ R. B. Gildea.
„ K. S. Gopalachari, B.A.
„ J. O'C. Fitzpatrick.
„ A. J. Moore, to 23rd July 1914.

Upper Subordinate Service.

Mr. Damodar Kadilkur, promoted from 1st July 1914.

Lower Subordinate Service.

32 Surveyors, etc.

The general nature of the country was varied, parts of the northern area were intricate and similar to that surveyed in previous years while towards the south and west it became more open and easy.

The field season opened on the 27th October 1913 and closed on the 26th April 1914. The field head-quarters was at Bāsim.

The health of the party was on the whole good. A certain amount of cholera was prevalent in the country under survey and one surveyor had a severe attack but fortunately recovered. There were five deaths in the menial establishment.

Topography.—The work was divided among three camps as follows :—

No. 1 camp under the officer in charge consisted of 4 surveyors and carried out the survey on the 1-inch scale of sheets $55\frac{D}{12, 16}$ and of part of sheet $56\frac{A}{9}$. Mr. Gopalachari joined about the middle of March.

No. 2 camp under Mr. Kitchen consisted of 10 surveyors and completed the survey on the 1-inch scale of sheets $55\frac{D}{9, 10, 11, 13, 14, 16}$ and on the 2-inch scale of the reserved forests in $55\frac{D}{2, 6}$, $56\frac{A}{9}$.

No. 3 camp under Mr. Gildea consisted of 8 surveyors and completed on the $\frac{1}{2}$-inch scale the survey of sheets $56\frac{A}{N.E., S.E.}$, $56\frac{E}{S.W.}$ and carried out on the 2-inch scale the survey of the reserved forests in sheets $55\frac{D}{3}$, $56\frac{A}{1}$.

Good progress was made with the $\frac{1}{2}$-inch survey which was only commenced last year, the country in which this class of survey was carried out was for the most part open and easy to survey but contained a fair proportion of broken and hilly ground. The areas surveyed were 171 square miles on the 2-inch scale, 2,268 square miles on the 1-inch scale and 3,086 square miles on the $\frac{1}{2}$-inch scale, making a total outturn of 5,525 square miles. The monthly average outturn per man on the three different scales was 8·8, 23·7 and 83·4 square miles respectively and the cost-rate was Rs. 34·8, Rs. 9·7 and Rs. 3·6 per square mile respectively.

The cost-rate for the area surveyed on the 2-inch scale includes the plane-table surveys on the 4-inch scale of the reserved forest boundaries amounting to 314 linear miles and as a matter of fact 15 out of the 171 square miles given as the area surveyed on the 2-inch scale were actually surveyed on the 4-inch scale. This survey on the 4-inch scale was undertaken in the case of the reserved forest in $55\frac{D}{3}$, the boundary and the detailed survey being combined; this action was economical on account of the very intricate boundary which was about 84 miles in perimeter and the very small area of the forest which was only 7 square miles.

Triangulation.—The triangulation of sheets $47\frac{M}{1 \text{ to } 16}$, $47\frac{N}{9, 10, 13, 14}$, $56\frac{A}{2, 3, 4, 6, 7, 8}$, $56\frac{B}{1, 2, 5, 6, 9, 13}$ was carried out by Messrs. Meyer, Gopalachari (until about the middle of March), Fitzpatrick and Moore. The country was open and easy to triangulate. The total outturn of triangulation was 8,985 square miles and the cost-rate was Rs. 2·9 per square mile.

Recess duties.—The fair mapping was divided among three sections as follows :—

No. 1 section under Mr. Meyer, sheets $55\frac{D}{12, 14, 15, 16}$.

No. 2 section under Mr. Kitchen, sheets $55\frac{D}{9, 10, 11, 13}$, $56\frac{E}{S.W.}$.

No. 3 section under Mr. Gildea, sheets $56\frac{A}{9, 13}$, $56\frac{A}{N.E., S.E.}$. Sheets $56\frac{A}{9, 13}$ only contained the areas falling in Berār.

The total outturn of fair mapping was 5,800 square miles and the cost-rate

was Rs. 4·2 per square mile. An area of 206 square miles was fair mapped on both the 1-inch and $\frac{1}{2}$-inch scales.

Computations sufficient for the work during the next field season were completed, and the balance will be completed during the field season. No triangulation charts were completed.

NOTE.—*Plane-table sections.*—Bristol boards mounted loose on wooden plane-tables with corner clips and aluminium, and venesta plane-tables mounted with drawing paper and cloth, were used in the field. The first method proved most satisfactory. Apart from the question of distortion the surface of any kind of drawing paper, mounted in a damp condition and afterwards constantly exposed to the sun, deteriorates to such an extent that in a few months it approaches a condition resembling blotting paper.

Telescopic clinometers.—Were issued to surveyors employed on survey on the $\frac{1}{2}$-inch scale and gave satisfaction. These instruments give good results in country where triangulated points are comparatively few, but have no great advantage over the Mathematical Instrument Office pattern for normal work on large scales.

No. 7 PARTY (MADRAS).

BY CAPTAIN J. D. CAMPBELL, R.E.

The work of the party included survey and supplementary survey in the Salem, North Arcot, South Arcot and Chittoor districts of Madras and in the Kolār district of Mysore and triangulation in the North Arcot, South Arcot, Chingleput and Chittoor districts of Madras and in French territory near Pondicherry.

PERSONNEL.

Imperial Officers

Lieutenant-Colonel F. W. Pirrie, I.A., in charge from 8th September 1914.

Captain J. D. Campbell, R.E., in charge up to 7th September 1914.

Provincial Officers.

Mr. J. O'B. Donaghey.

„ P. R. Anderson.

„ C. West.

„ H. D. W. Stotesbury, up to 30th October 1913.

„ H. H. P. Butterfield.

„ J. C. St. C. Pollett.

Upper Subordinate Service.

Mr. Abdul Hakk, K. S., from 18th November 1913.

„ Kodandera Mandanna.

Lower Subordinate Service.

28 Surveyors, etc.

The general nature of the country surveyed varied in character. It consisted of forest clad hills the greater part of which were reserved forests, lower rocky hills covered with scrub or almost devoid of vegetation and open cultivated plains.

The head-quarters of the party remained at Bangalore and the party took the field on various dates between the 5th October and the 17th November 1913 and returned to recess quarters between the 29th April and the 23rd May 1914.

The health of the party was good.

Topography.—The work was divided among three camps as follows:—

No. 1 Camp.—Under Mr. Donaghey which varied in strength from 8 to 15 surveyors carried out survey on the 1-inch scale of 908 square miles and supplementary survey on the 1-inch scale of 509 square miles in sheets $57\frac{L}{5,\,6,\,9,\,10,\,13}$.

No. 2 Camp.—Under Mr. West which varied in strength from 6 to 11 surveyors carried out survey on the 2-inch scale of 168 square miles of reserved forests and on the 1-inch scale of 743 square miles and supplementary survey on the 1-inch scale of 542 square miles in sheets $57\frac{L}{11,\,12,\,15,\,16}$, and $57\frac{P}{2}$.

No. 3 Camp.—Under Mr. Pollett consisted of 11 surveyors and carried out survey on the 2-inch scale of 9 square miles of reserved forests and on the 1-inch scale of 1,390 square miles and supplementary survey on the 1-inch scale of 52 square miles in sheets $57\frac{L}{2,\,3,\,4,\,7,\,8}$.

In addition to the above Mr. Abdul Hakk, K. S., carried out 290 square miles of supplementary survey on the 1-inch scale in sheet $57\frac{L}{14}$.

The areas completed were as follows:—

Survey on the 2-inch scale of 177 square miles of reserved forest in sheets $57\frac{L}{8,\,12,\,15,\,16}$, $57\frac{P}{4}$.

Survey on the 1-inch scale of 3,041 square miles in sheets $57\frac{L}{2,\,3,\,4,\,5,\,6,\,7,\,8,\,9,\,10,\,11,\,12,\,13,\,14,\,15,\,16}$, $57\frac{P}{2}$.

Supplementary survey on the 1-inch scale of 1,393 square miles in sheets $57\frac{L}{2, 3, 4, 5, 6, 8, 9, 10, 11, 12, 13, 14, 15, 16}$, $57\frac{P}{2}$.

The 2-inch forest survey presented no difficulties except in the case of one or two reserves in flat country which are very dense and had to be traversed everywhere, fixings being obtainable at rare intervals. The 1-inch survey was easy. The Madras Revenue Survey work was of considerable assistance and was found accurate. The 1-inch supplementary survey was mainly revision of 4-inch forest surveys. The 4-inch work was found accurate and was merely checked, slightly supplemented and re-contoured. The re-contouring was necessary owing to the 4-inch heights being wrong, but the contouring was greatly assisted by the 4-inch maps which show the ground well.

The total outturn of the party was 4,611 square miles, with a cost-rate for 2-inch survey, 1-inch survey and 1-inch supplementary survey of Rs. 24·0, Rs. 10·7 and Rs. 8·9 respectively, this gives a general cost-rate of topography per square mile of Rs. 10·7. The average outturn per man per month in the three classes of survey was 11·5, 32·9 and 57·3 square miles respectively.

Triangulation.—The triangulation of sheets $57\frac{P}{9, 10, 11, 12, 13, 14, 15, 16}$, $57\frac{O}{3, 4, 7, 8, 11, 12, 15, 16}$, $66\frac{D}{1, 2, 3, 4, 5}$, was carried out by Messrs. Anderson, Butterfield and Mandanna under the general superintendence of Mr. Anderson.

The triangulation presented some difficulties as a good deal of the ground triangulated is practically flat, there being a few rocky knolls on which stations could be made. The difficulty was increased by the numerous palmyra and other trees and it was impossible to fix many good points for plane-tablers over a good deal of the ground. A chart on the $\frac{1}{4}$-inch scale was obtained from the Madras Revenue Survey showing their principal traverse lines and about 90 of their traverse stations were picked up. These have worked out well and the average difference in position between the Survey of India and Madras Revenue values is less than can be measured on the scale of survey. It is expected that, by plotting the Revenue traverse points which are all village trijunctions, the difficulties of survey in the flat ground will be overcome.

The total area triangulated was 5,226 square miles and the cost-rate was Rs. 4·7 per square mile.

Recess duties.—The fair mapping was divided among five sections as follows:—

No. 1 section under Mr. Donaghey, sheets $57\frac{L}{5, 6, 9, 10}$.

No. 2 section under Mr. Anderson, sheets $57\frac{L}{13}$, $57\frac{P}{2}$.

No. 3 section under Mr. West, sheets $57\frac{L}{11, 12, 15, 16}$.

No. 4 section under Mr. Pollett, sheets $57\frac{L}{3, 4, 7, 8}$.

No. 5 section under Mr. Abdul Hakk, sheets $57\frac{L}{2, 14}$.

All the fair mapping will be completed and the sheets submitted by the end of the recess season.

The total outturn of fair mapping was 4,642 square miles and the cost-rate was Rs. [illegible]·4 per square mile.

The computation of all the triangulation will be completed by the end of the recess season. No triangulation charts were completed.

No. 8 PARTY (MADRAS).

BY CAPTAIN C. M. BROWNE, D.S.O., R.E.

The work of the party included survey in the Travancore State of Madras, triangulation in the Coimbatore, Madura and Tinnevelly districts and in the Travancore State of Madras and traversing in the Travancore State of Madras.

PERSONNEL.

Imperial Officers.

Captain C. M. Browne, D.S.O., R.E., in charge.

The general nature of the country varied in character ranging from the densely

PERSONNEL—*contd.*

Provincial Officers.

Mr. W. F. E. Adams.
„ S. F. Norman.
„ J. H. Williams.
„ P. Kennegy.
„ M. Mahadeva Mudaliar, B.A.

Upper Subordinate Service.

Mr. Anantarao Dhondiba Mandhre, K.S.
„ K. Narayanasvami Chetti.
„ P. S. Vengusvami.

Lower Subordinate Service.

36 Surveyors, etc.

inhabited country on the coast to the unexplored portions of the Pandalam hills which may be described as high rugged mountains covered with a dark impenetrable forest.

The field season opened on the 17th November 1913 and closed on the 8th June 1914. The field head-quarters was at Pirmed.

The health of the party was fair considering the climatic conditions, those working on the high range suffered a good deal from the cold and rain while in the dense forests leeches were very troublesome.

Topography.—The work was divided into four camps as follows:—

No. 1 Camp.—Under Mr. Adams consisted of Mr. Vengusvami and 9 surveyors and carried out the survey on the 1½-inch scale of sheets 58 $\frac{C}{7,8}$ and of the western half of sheet 58 $\frac{C}{12}$. In this area only the huts of a more permanent character were surveyed and a note will be added on the published maps to the effect that, except in areas shewn as water or cultivation, the whole country consists of dense palm groves dotted about with numerous scattered huts. The land is very flat and lowlying, there being no contours whatever in sheets 58 $\frac{C}{7,8}$.

No. 2 Camp.—Under Mr. Norman consisted of 8 surveyers and carried out the survey on the 1-inch scale of sheet 58 $\frac{C}{16}$ and of the eastern half of sheet 58 $\frac{C}{12}$. The latter sheet is fairly thickly inhabited but the former includes large areas of forest.

No. 3 Camp.—Under Mr. Williams consisted of Mr. Narayanasvami Chetti and 7 surveyors and completed the survey on the 1-inch scale of sheets 58 $\frac{C}{15}$, 58 $\frac{G}{3}$ and on the 1½-inch scale of sheet 58 $\frac{D}{10}$; sheet 58 $\frac{G}{3}$ included part of the unexplored portion of the Pandalam hills, a country practically unknown and uninhabited and very difficult of access. Complete arrangements had to be made for provisions as none were obtainable locally and depôts for supplies were established in suitable places. The work was very difficult and the officers and men underwent hardships.

No. 4 Camp.—Under Mr. Anantarao Dhondiba Mandhre consisted of 7 surveyors and carried out the survey on the 1-inch scale of sheet 58 $\frac{D}{13}$. This sheet was full of very intricate detail.

Owing to the extremely intricate nature of the country the survey along the coast was continued on the 1½-inch scale, but it is expected that the necessity for the employment of this scale will cease after next field season. There was no country where any large outturn could be made and in consequence the area surveyed was less than during the previous year.

The areas surveyed were 1,223 square miles on the 1-inch scale and 343 square miles on the 1½-inch scale, making a total outturn of 1,566 square miles. The monthly average outturn per man on the two scales was 9·9 and 5·8 square miles respectively and the cost-rate was Rs. 46·7 and Rs. 55·4 per square mile respectively.

Triangulation.—Mr. Kennegy completed 391 square miles of triangulation in sheets 58 $\frac{H}{3,4,7,8,12}$ and afterwards, in conjunction with Mr. Mahadeva Mudaliar completed 614 square miles in sheets 58 $\frac{F}{3,4,7,8}$. The total area triangulated was 1,005 square miles and the cost-rate was Rs. 17·8 per square mile.

Traversing.—A surveyor and a traverser carried out 55 linear miles of traversing in sheets 58 $\frac{D}{9,10,14}$. The cost-rate was Rs. 67·3 per linear mile.

Recess duties.—The fair mapping was divided between two sections as follows:—

No. 1 section under Mr. Adams, sheets $58\frac{C}{7,8,12,16}$ and the arrears in sheets $58\frac{C}{10,11}$ were completed.

No. 2 section under Mr. Williams, sheets $58\frac{C}{15}$, $58\frac{G}{3}$, $58\frac{D}{10,13}$ and the arrears in sheets $58\frac{C}{14}$, $58\frac{G}{1,2}$.

All the fair mapping should be completed by the end of the recess season. The total outturn of fair mapping was 1,809 square miles and the cost-rate was Rs. 16·3 per square mile.

The computation of all the triangulation and the preparation of degree chart 49 M will be completed by the end of the recess season.

Tinnevelly-Travancore Boundary.—Owing to disputes regarding sections 5, 6, 9 and 10 of this boundary it was decided to undertake a special survey of these sections and to have representatives of Tinnevelly and Travancore present at the survey, these representatives were to agree to the line taken or produce evidence why it should be changed. Sections 5 and 10 were surveyed and agreed to this year and sections 6 and 9 will be surveyed next year. The work this year necessitated 2 square miles being surveyed on the 4-inch scale and 5 linear miles being traversed.

The question of this boundary has been pending for the best part of a hundred years, the chief obstacle being the extraordinary inaccessibility of sections 5 and 6 owing to the precipitous nature of the hills and the wildness of the country a great part of which has never been surveyed and is almost unknown.

Kirkee Wireless Station.—At the beginning of August 1914 Captain Browne with 3 surveyors, etc., proceeded to Kirkee to assist in the erection of the installation.

The following work was required:—

1. The survey of about 3 square miles on the scale of 16 inches to 1 mile with 10 feet contours.
2. The survey of the actual sites of the power station and residential quarters on a scale of 64 inches to 1 mile with $2\frac{1}{2}$ feet spirit levelled contours.
3. The determination of the latitude, longitude and height of the sending station at Kirkee and of two alternative receiving stations at Peth and Nārāyangaon with their mutual azimuths and distances.
4. The laying down of lines of given azimuth at Kirkee, Peth and Nārāyangaon.
5. Determination of the height of the station at Kirkee from the standard bench-mark by spirit levelling.

All the above work with the exception of the survey on the scale of 16 inches to 1 mile was completed on the 17th September 1914 when Captain Browne returned to Bangalore leaving one surveyor to complete the survey. The work was carried out under considerable difficulties owing to the monsoon being exceptionally severe this year.

EASTERN CIRCLE.

(*Vide* Index Maps 3 and 6.)

Summary.—The Circle was under the superintendence of Lieutenant-Colonel C. H. D. Ryder, D.S.O., R.E., up to 7th November, and Major A. Mears, I.A., up to 28th November 1913 from which date it was under Lieutenant-Colonel C. L. Robertson, C.M.G., R.E.

14,890 square miles were surveyed during the year, consisting of—

8,442	square miles of	1-inch survey.
3,462	do.	1-inch supplementary survey.
715	do.	1-inch revision survey.
1,695	do.	$\frac{1}{2}$-inch revision survey.
252	do.	2-inch survey.
302	do.	2-inch skeleton survey.
22	do.	4-inch survey.

No. 9 PARTY (BIHĀR AND ORISSA).

By Captain R. H. Phillimore, R.E.

This party completed the survey of sheet 73B surveying sheets $73\frac{B}{1,2,3,4,5,6,7,8}$ such parts of Rānchī district and Jashpur State (of the Central Provinces) as fall into this area were surveyed on the 1-inch scale; the remainder of this area falling into the Orissa Feudatory States was surveyed on the $\frac{1}{2}$-inch scale, $\frac{1}{2}$-inch survey was carried westwards into sheets 64N and 64O to complete the survey of Gāngpur State.

The party also surveyed on the 1-inch scale sheets $72\frac{L}{2,3,4,7,8}$ covering parts of Hazāribāgh, Monghyr and Mānbhūm districts.

A small area of reserved forests falling in sheet $72\frac{L}{7}$ was surveyed on the 2-inch scale.

The party commenced work in the field from November 10th, closing by May 10th. The country was all most healthy, and work proceeded steadily right through the season.

Personnel.

Imperial Officers.

Captain R. H. Phillimore, R.E., in charge till September 20th.
Captain E. B. Cardew, R. E., attached from September 4th to 20th and in charge from September 21st 1914.

Provincial Officers.

Mr. Dhani Ram Verma.
" B. C. Newland.
" L. B. Fitz-Gibbon.
" A. K. Mitra.
" V. P. Wainright.
" W. P. Hales.
" D. N. Banerjee, B.A.

Upper Subordinate Service.

Mr. Dalbir Rai.
" Ram Singh.

Lower Subordinate Service.

37 Surveyors, etc.

There was a very large number of beginners under instruction; out of 33 men employed on plane-tabling no fewer than 17 men were under instruction for their first or second season.

Topography.—The country under survey in Rānchī and Jashpur lay on the Chotā Nāgpur plateau. The highest ground rises to just 3,200 feet in Jashpur, and is broken up into numerous small plateaus of about the same level, each of a few square miles in area, flat topped and well wooded. This ground was found difficult to triangulate, and it will be seen that the Sambalpur meridional series, of the principal triangulation, makes an abrupt departure from its ruling meridian 84° in order to avoid this patch of ground. The plateau descends towards the south by a series of rocky broken scarps; the drop from one level to the next not much exceeding 500 feet. These scarps run generally east and west and have passes through them at certain points, which are just practicable for cart traffic. The stretches of land between the scarps are undulating and well populated by Uraons and other aboriginal tribes, and are cultivated and generally covered by scattered trees. Fixings could be readily obtained over all this country, but none of the ground was suitable for rapid hill sketching.

The plateau drains into the river Sankh which descends from a level of 2,100 feet in sheet $73\frac{B}{6}$ to a level of 770 feet in sheet $73\frac{B}{7}$ where it leaves Rānchī to flow into Gāngpur State.

The country surveyed in Gāngpur State is mostly undulating and wooded, with rocky hill ranges rising to about 1,600 feet above sea level. The drainage falls into the Ib river which flows out of Gāngpur State at a level of 650 feet above the sea.

Surveyors working on the ½-inch scale found it impossible to survey from interpolated fixings only; and resort had in many places to be made to plane-table traverses. Owing to the smallness of the scale chaining would have been tedious and unsatisfactory and it was found that good results could be obtained from pacing, even in rough ground.

In particularly wooded areas plane-tablers got the direction of their traverse lines by taking rays to the shout of a man; small megaphones were made up and issued to the men, and rays could be taken with sufficient accuracy up to a distance of 25 chains. In running traverse lines by this "pace and shout" method it was found that the closing error at the end of a 5 mile traverse seldom exceeded 10 chains. If fixings could not be obtained such errors were adjusted and controlled by running tie lines. Before the issue of megaphones rays could not be taken to the unaided voice to a distance much greater than 15 chains, and traverses did not close with sufficient accuracy when plotted by such short lengths.

In sheet 72L the country surveyed is of a general level from 800 feet to 1,000 feet, and is undulating; in parts the country is well cultivated and open but there are patches of rough wooded ground where survey was slow and fixings very difficult to obtain.

The party was divided into three camps the head-quarters being at Rānchī.

Camp No. I.—Under Mr. B. C. Newland consisted of 12 plane-tablers, of whom 6 were beginners under the direct supervision of Mr. Dalbir Rai. This camp was responsible for all the 1-inch work in 73B.

Camp No. II.—Under Mr. W. P. Hales carried out all the ½-inch work. Mr. Hales surveyed 136 square miles himself besides supervising the work of 5 surveyors.

Camp No. III.—Under Mr. D. R. Verma surveyed the 5 sheets in 72L. Of 15 men, 9 were absolute beginners, and surveyor Ghulam Haidar was employed as an instructor throughout the season.

Reductions of cadastral maps compiled into 1-inch sheets were again issued for the topographical supplementary survey of Rānchī, Hazāribāgh and Monghyr districts. In the flatter ground of sheet 72L a great deal of value was obtained from them; but surveyors do not yet take full advantage of all the material thus provided.

Triangulation.—Triangulation in sheet 72P was entrusted to Mr. D. N. Banerjee and Mr. Ram Singh who completed 1,632 and 1,800 square miles respectively.

Mr. A. K. Mitra was employed for about a month on supplementary triangulation in sheet $72\frac{L}{8}$ covering 400 square miles of area previously reported. The observations were computed in the field in order to provide extra points for the plane-tablers. The cost-rate of the whole area of 3,832 square miles is Rs. 2·2 per square mile.

Traversing.—In the Santāl Parganas and Hazāribāgh district 108 miles of traverse was executed for forest boundary surveys by Mr. Banerjee, surveyor Khalil-ur-Rahman and computer Kanhya Lal; the cost-rate being Rs. 25·9 per mile. Surveyor Khalil-ur-Rahman also traversed 245 linear miles in sheets $72\frac{P}{12, 13, 14, 15 \text{ and } 16}$; the cost-rate of this traverse is Rs. 8·4 per mile. No heights have been fixed in this area which is so flat that contours will not be shewn.

Recess duties.—During recess the fair mapping was completed under the supervision of the following officers:—

Mr. Dhani Ram Verma; sheets $72\frac{L}{2, 3, 4, 7, 8}$.

Mr. B. C. Newland; sheets $73\frac{B}{1, 2, 5, 6}$.

Mr. A. K. Mitra; sheets 73 $\frac{B}{3 \text{ and } 7}$.

Mr. W. P. Hales; $\frac{1}{2}$-inch sheets 64 $\frac{N}{S.E.}$ and $\frac{O}{N.E.}$, 73 $\frac{B}{S.W.}$ and 73 $\frac{F}{S.W.}$.

Field sections were brought in with no distortion at all, and direct mapping could be adopted for some portion of every one of the sheets dealt with. Much time was thereby saved, and no outline sheets had to be sent down for vandyking.

The computation of the triangulation carried out by Mr. D. N. Banerjee and Mr. Ram Singh in sheet 72P was carried out during the recess season.

Rough triangulation charts for sheets 72L and 73B, F with manuscript lists of data were prepared for submission to the Superintendent of the Trigonometrical Survey and the computation volumes and general reports on triangulation in sheets 73B and F were completed; this work for the greater part was under the supervision of Mr. V. P. Wainright.

The computation of all the traverse work done in the field season was computed during recess under the supervision of Mr. L. B. Fitz-Gibbon. Owing to a change in the party's programme the data obtained from the traverse work in 72 $\frac{P}{12 \text{ to } 16}$ will not be required for some years to come, plots of the circuits have therefore not been made.

No. 10 PARTY (UPPER BURMA).

BY MAJOR E. T. RICH, R.E.

The recess office of the party closed in Maymyo on October 24th, 1913, and opened in Myitkyinā on October 28th, 1913.

PERSONNEL.

Imperial Officers.

Major E. T. Rich, R.E., in charge to 23rd May 1914 and from 12th September to 30th September 1914.

Captain L. G. Crosthwait, I.A., in charge from 24th May to 11th September 1914.

Lieutenant W. E. Perry, R.E., attached up to 10th May 1914.

Lieutenant H. E. Roome, R.E., attached from 1st November 1913.

Provincial Officers.

Mr. J. Smith.
" W. G. Jarbo.
" H. B. Simons.
" V. W. Morton.
" Asmat-Ullah Khan, K. S.
" C. B. Sexton.
" A. F. Murphy.

Upper Subordinate Service.

Mr. Lachman Daji Jadu, R. B., to 14th May 1914.
" Hayat Muhammad, K. S.
" Maung Kyaw Nyein to 3rd February 1914 and from 4th August to 30th September 1914.

Lower Subordinate Service.

33 Surveyors, draftsmen, etc.
6 Pupils.

The office at Myitkyinā was closed on May 10th, 1914, and the recess office was reopened in Maymyo on May 12th, 1914, where it remained for the rest of the year.

The country under survey lay in the Myitkyinā, Kathā and Mandalay districts of Upper Burma, nearly the whole area being covered with densely wooded hills and valleys, whilst great varieties in height were experienced. The low lying Kaukkwe valley in the north-east of the Kathā district was less than 500 feet above sea level, whilst some of the snowy peaks along the Burma-China border in the Htawgaw hill tracts, to the north-east of the Myitkyinā district, were nearly 14,000 feet high. The whole area surveyed in the Htawgaw hill tracts was thinly populated, and no supplies could be obtained locally. As most of the area was over 10 days' march distant from Myitkyinā, considerable difficulty and expense were incurred in rationing the surveyors.

The climate was extremely cold from November to January, and from February onwards rain was frequent. In order to complete the survey of the high hills, which are inaccessible in winter, 3 surveyors were left to complete the work during the summer months.

In the Kathā district, the survey of the Kaukkwe valley was difficult owing to the country being one vast low lying forest with practically no inhabitants, but the area to the west of this district near the railway was of a

totally different character, as a considerable portion of the ground was cultivated and villages were numerous. The area surveyed in the Mandalay district round Maymyo was of the same description as that near the railway line in the Kathā district.

The health of the party was very good during the whole season, except for a few cases of malaria.

Topography.—Surveys were completed over an area of 4,763 square miles at a cost of Rs. 1,03,230 in sheets $92\frac{D}{3,\,4,\,6,\,10,\,13}$, $92\frac{G}{2,\,3,\,6,\,13\text{ (part)}}$, $93\frac{B}{\text{parts of }(8,\,12)}$, $93\frac{C}{\text{part of }(5)}$.

This area was surveyed as follows :—

	4,024	square miles of new	one-inch survey
	92	do.	two do.
	587	do.	one-inch revision survey.
	60	do.	one-inch reconnaissance in unadministered territory.
TOTAL	4,763	square miles.	

The party was divided into three survey camps under Major E. T. Rich, R. E., Mr. W. G. Jarbo and Mr. Asmat-Ullah Khan, K. S., respectively, whilst Mr. J. Smith was in charge of the two Land Records Officers who were instructed in surveying the Maymyo Forest Reserve.

Camp No. 1.—In charge of Major Rich, with 1 Upper Subordinate and 2 surveyors, completed an area of 806 square miles in sheets $92\frac{G}{2,\,3,\,6}$ on the 1-inch scale; in addition 424 square miles of one-inch revision survey round Maymyo were surveyed by 2 Upper Subordinates and 2 surveyors, in sheets $93\frac{B}{8,\,12}$, $\frac{C}{5}$. This latter area is small, as the 2 Upper Subordinates only worked for a short period and the 2 surveyors only during the recess, when rain was frequent.

The whole of the area surveyed by this camp consisted of thickly wooded hills.

Camp No. 2.—In charge of Mr. W. G. Jarbo, with 1 Imperial officer, Lieutenant H. E. Roome, R.E., under instruction, and 7 surveyors, completed an area of 2,142 square miles on the one-inch scale in sheet $92\frac{G}{13\text{ (part)}}$ and parts of certain sheets in unadministered territory inclusive of 60 square miles of reconnaissance survey.

Practically the whole of this area lay adjacent to the Burma-China Border, and was sparsely inhabited with thickly wooded hills, rising from 8,000 to 13,000 feet high, the higher peaks being covered with snow. Owing to heavy snow, the highest hills could not be surveyed during the winter, so 3 surveyors were left to complete them during the summer months. All rations for this camp had to be carried on mules from Myitkyinā, a distance of 10 to 15 days' march from the work. Mr. W. G. Jarbo arranged all the rationing himself in a very able and economical manner.

Camp No. 3.—In charge of Mr. Asmat-Ullah Khan, K. S., with 1 Imperial officer, Lieutenant W. E. Perry, R.E., under instruction, 1 Provincial officer, Mr. A. F. Murphy, 7 surveyors and 5 pupils completed an area of 1,356 square miles in sheet $92\frac{D}{3,\,4,\,6,\,10,\,13}$ consisting of 1,136 square miles of new survey on the 1-inch scale, 57 square miles of reserved forests on the 2-inch scale and 163 square miles of 1-inch revision survey over forests previously surveyed on the 4-inch scale. The country in this camp was lowlying and thickly wooded with very few inhabitants, the progress was therefore very slow as nearly all the work had to be done by chaining.

The Land Records Instruction camp.—In charge of Mr. J. Smith with 2 Land Records probationers, Messrs. Kong Mein and Nicholas, completed the survey of the Maymyo Reserve in sheets $93\frac{B}{8,\,12}$, $\frac{C}{5}$, an area of 35 square miles on the 2-inch scale.

Triangulation.—New triangulation was completed over an area of 6,150 square miles at a cost of Rs. 51,730 including the computations.

(*a*) Mr. H. B. Simons triangulated an area of 2,000 square miles in sheets $92\frac{B}{9, 16}$, $92\frac{F}{2, 4}$ of transfrontier territory in the Hukawng valley.

(*b*) Mr. V. W. Morton triangulated an area of 1,000 square miles, in certain sheets of the Htawgaw hill tract, along the Burma-China frontier.

(*c*) Mr. C. B. Sexton triangulated an area of 1,350 square miles, in sheets $92\frac{C}{9, 10, 11, 13, 14, 15}$, of the Myitkyinā district.

(*d*) Surveyor Ram Prasad triangulated an area of 1,800 square miles, in certain sheets of the Htawgaw hill tract and in sheets $92\frac{G}{1, 5}$, of the Myitkyinā district.

Great credit is due to the arrangements made by Messrs. H. B. Simons and V. W. Morton and surveyor Ram Prasad who were working under great difficulties, over a fortnight's march from their base in Myitkyinā, whence all provisions, etc., had to be carried. They managed their own arrangements entirely by themselves, and everything went off well. The same kind of country was triangulated by all four triangulators, consisting of thickly wooded hills and deep valleys sparsely inhabited.

Traversing.—(*a*) During the field season Lieutenant W. E. Perry, R.E., was in charge of all traversing and traverse computations, in addition to doing plane-tabling in camp No. 3.

During the whole season 2 traversers and 1 computer were continuously employed and Lieutenant H. E. Roome, R.E., from camp No. 2, with 2 pupils from camp No. 3, joined the traverse camp towards the end of the field season for 2 months.

Four-inch theodolite boundary traverses were completed round the Nantan Puga, Nansonti, Teinon, Manmaw, Mawhun and Loimaw reserve forests, in sheets $92\frac{D}{2, 5, 9, 13}$, totalling 146 linear miles.

(*b*) 9 linear miles of ordinary theodolite traverse were run inside these reserves, as a help to the plane-tablers.

(*c*) During the recess season, 2 traversers, under the charge of Lieutenant H. E. Roome, R.E., completed four-inch theodolite boundary traverses round the Taungbyo, Sakangyi and part of the Zibyingyi reserves, in sheets $93\frac{B}{8}$, $\frac{C}{5}$, totalling 128 linear miles.

(*d*) During the winter, the two Land Records probationers, Messrs. Kong Mein and Nicholas, traversed and computed a four-inch theodolite boundary traverse round the Maymyo reserve, in sheets $93\frac{B}{8, 12}$, $\frac{C}{5}$, totalling 43 linear miles.

(*e*) These theodolite traverses total 317 linear miles of boundary traverse and 9 linear miles of ordinary traverse. In addition, 13 linear miles of plane-table traverse on the four-inch scale were run round small extensions of the Nami and Nansiaung reserve forests, in sheet $92\frac{D}{3}$, so that the total length of forest boundary traverse comes to 330 linear miles, and of ordinary traverse to 9 linear miles.

(*f*) The total length of traverse for cost-rates, etc., is however calculated as only 326 linear miles, excluding these 13 linear miles of plane-table traverse, which only appear in the totals of the forest return and in the precis, but nowhere else.

(*g*) The outturn was small owing to the dense jungle encountered everywhere, which made progress very slow.

The total cost of traversing and its computations amounts to Rs. 22,519. The cost-rate per linear mile is worked out excluding work done by pupils and Land Records probationers.

Recess duties—(*a*) The fair mapping was divided into two sections:—

No. 1 Section.—In charge of Mr. W. G. Jarbo assisted by Mr. A. F. Murphy drew sheet $92\frac{G}{6}$, which will be sent for publication

before the party takes the field, and part of sheet 92 $\frac{G}{15}$, of which the survey is not yet completed.

No. 9 Section.—In charge of Mr. Asmat-Ullah Khan, K. S., assisted by Mr. C. B. Sexton, drew sheets 92 $\frac{D}{3, 4, 6, 10, 13}$, $\frac{G}{2, 3}$, which will be sent for publication before the party takes the field.

(*b*) The computations of the season's triangulation and traversing were completed during the recess in charge of Mr. H. B. Simons, assisted by Mr. V. W. Morton, Mr. Hayat Muhammad, K. S. and two computers.

The triangulation computations were very heavy, and were not completed till the end of September, giving no time for the preparation of the triangulation charts.

Outturn and cost-rates.—The cost-rates show a large reduction all round, whilst the area of 4,763 square miles surveyed by the party is nearly double the area of 2,496 square miles surveyed last year.

This increase of area is partly due to 5 surveyors being employed on surveying during the recess, but is also largely due to the increased efficiency of the personnel of the party.

The cost-rates for each class of operation have been reduced, for 1-inch survey by Rs. 2·83 per square mile, for 2-inch survey by Rs. 3·33 per square mile, for triangulation and mapping by Rs. 5·1 and Rs. 3·4 respectively per square mile and for forest boundary traversing by Rs. 40 per linear mile.

No. 11 PARTY (LOWER BURMA).

BY CAPTAIN L. G. CROSTHWAIT, I. A.

The party arrived in Tavoy, which was again the field head-quarters at the end of October 1913, and returned to Maymyo at the beginning of May 1914.

The country surveyed lay in the south of the Tavoy district, between the sea coast and the Siam frontier. The programme of the party, which included the South Moscos Islands, was completed. The nature of the country was similar to that surveyed the previous year, varying from tidal creeks to densely wooded and uninhabited hills rising to nearly 7,000 feet.

PERSONNEL.

Imperial Officers.

Captain L. G. Crosthwait, I.A., in charge up to 22nd May 1914 and from 13th September 1914.

Lieutenant F. J. M. King, R.E., attached from 30th March to 22nd May and from 13th September 1914, and in charge from 23rd May to 12th September 1914.

Provincial Officers.

Mr. A. M. Talati.
" T. P. Dewar, up to 1st June 1914.
" F. E. R. Calvert, from 11th September 1914.
" A. J. Booth.
" R. M. Wyatt.

Upper Subordinate Service.

Mr. Raghubar Datt Thaplyal, from 27th January to 3rd August 1914.

Lower Subordinate Service.

29 Surveyors, etc.

The keeping up of the supply of rations for surveyors, some 200 khalasis and 60 or 70 mules in the Ban Chaung and Tenasserim River valleys with the limited amount of transport available presented the chief difficulty in carrying out the survey. The only road into this area was a disused and very steep path over the hills, or along the rocky beds of streams in the valleys. Rations were sent out by mules to depots at Ban Chaung and Amya villages, the latter being about two weeks' march from Tavoy. From these places they were taken to the surveyors by men of their squads, which, for jungle cutting and transport purposes, were increased to 20 men each. The mules were brought down by the party from the Yün-nan frontier of the Northern Shan States.

The health of the party was fair only. One surveyor and two khalasis died during the season.

Topography.—The area surveyed comprising sheets 95 $\frac{G}{13}$, $\frac{J}{11, 12}$, $\frac{K}{1, 2, 5, 6, 9,}$ $\frac{K}{10, 13, 14}$, $\frac{O}{1, 2}$ and parts of sheets 95 $\frac{K}{7, 11, 15}$ was 2,437 square miles of 1-inch survey, 62 square miles of 1-inch revision survey and 95 square miles of forest on 2-inch scale, 90 square miles of which was reserved forest, a total of 2,594 square miles. The revision survey was part of sheet 95 $\frac{J}{11}$, which was surveyed the previous year, but which it was found necessary to revise. The party was divided

up into three camps under Messrs. T. P. Dewar, A. J. Booth, and R. M. Wyatt.

Triangulation.—Mr. A. M. Talati triangulated an area of 2,200 square miles in the Mergui district in sheets 95 L and P. The triangulation was based on the Eastern Frontier Series principal triangulation of 1877.

Traversing.—Computer Annada Prasad Ghosh carried out a theodolite traverse of the Western Hill Range reserved forest a distance with connecting lines of 66·4 linear miles.

Recess duties.—The fair mapping was divided into two sections, one under Mr. A. J. Booth, which drew sheets 95 $\frac{G}{13}$, $\frac{K}{1, 2, 5, 6, 10}$, and the other under Mr. R. M. Wyatt, which drew sheets 95 $\frac{J}{11, 12}$, $\frac{K}{9, 13, 14}$, $\frac{O}{1, 2}$.

The season's triangulation was computed during the recess and fair plots made of the forest boundary traverse.

Triangulation charts with tables of data were prepared for 95 G, K, and O.

Cost-rates.—As anticipated in last year's report the cost-rates for detail survey have increased. This is due to higher rates of local labour and mule hire, and an increased number of mules being required to keep up the supply of rations. The hire of mules and their freight to and from Tavoy form the largest item of expenditure in carrying out the survey of this district.

The rates for triangulation, traversing and fair mapping and the all-in cost are less than for last year. This is due to greater outturns.

No. 12 PARTY (ASSAM).

BY MAJOR A. MEARS, I. A.

The previous season's operations were extended eastward on both banks of the Brahmaputra river from the boundary of Tòwang and the Akā Hills on the north to Latitude 26° on the south, and, to the east, included a portion of the Mīkīr Hills.

PERSONNEL.

Imperial Officers.

Major A. Mears, I.A., in charge excepting period 8th to 30th November 1913.

Provincial Officers.

Mr. W. Skilling.
„ Pramadaranjan Ray, R. S., in charge from 8th to 30th November 1913.
„ E. Claudius, from 6th July 1914.
„ E. M. Kenny.
„ Amjad Ali, till 21st April 1914.
„ L. Williams, till 25th October 1913.
„ P. C. Mitra, B.A.
„ H. H. Creed.

Upper Subordinate Service.

Mr. Nanak Chand Puri, B.A.
„ Sajoni Kumar Ghosal, till 19th November 1913.

Lower Subordinate Service.

44 Surveyors, etc.

The area comprised sheets 83 $\frac{B}{5, 10, 11, 12, 14, 15, 16}$ and 83 $\frac{F}{1, 2, 3, 4, 8}$ and embraced portions of districts Darrang, Nowgong and Sibsāgar.

The survey was carried out entirely on the 1-inch scale with the exception of the Chelabor, Sildharampur, Jungthung, Kukrakātā, Garumari, and Bhomoraguri reserves, covering an area of 34 square miles, which were surveyed on the 2-inch scale. In addition the forest reserves of Dabakā, Suang Bamoni and Diju valley, surveyed on the scale of 4-inch to the mile in seasons 1904-06, were revised; with the exception of the heights and contouring the work was found very good.

The special survey of the Upper Dihing and Jaipur reserves, commenced the previous season, was continued, the work being carried out partly on the 4-inch and partly on the 2-inch scale; the progress of this survey was exceptionally slow due to the very intricate nature of the ground and the denseness of the forest growth. The country under survey differed little from that described in previous reports. Where not under cultivation, the plains area was covered with high and impenetrable grass, rendering its mapping a difficult matter until dry enough to be burnt. Except where they had been "jhoomed," the hills were covered with dense jungle, in many parts evergreen, and fixings could only be obtained with heavy clearing; this necessitated considerable use of the chain.

Field work started about the middle of November and closed early in May on the commencement of the rains. The health of the party on the whole was

exceptionally good. A temporary traverser died very suddenly in April of fever and 2 khalasis died, one from cholera, the other of fever.

Topography.—The detail survey programme was executed by 4 camps under the charge of Messrs. Pramadaranjan Ray, R. S., E. M. Kenny, Amjad Ali and P. C. Mitra.

Mr. Pramadaranjan Ray, R. S., with a camp of one Sub-Assistant Superintendent and 9 surveyors, completed the survey of $4\frac{1}{2}$ sheets.

Mr. E. M. Kenny, with a junior Extra Assistant Superintendent and 8 surveyors, mapped an area equivalent to 3 sheets.

Mr. Amjad Ali, with 7 surveyors, carried out the survey of 4 sheets.

Mr. P. C. Mitra, with 4 surveyors, was employed on the special survey of the Upper Dihing reserve, where he completed an area of 20 square miles on the 2-inch and 22 square miles on the 4-inch scales.

Of the area under survey some 780 square miles were hilly, rising in the Mīkīr Hills to an elevation of 4,000 feet. The country round Nowgong and Tezpur is densely populated, and to the north of the latter place there are numerous tea gardens. Along the foot of the Mīkīr Hills, in the Nowgong district, tea is also extensively cultivated. The south-eastern portion of the Nowgong district, to the south of the Jamunā river, must have been at some period well populated, judging from the numerous tanks found scattered over the country. Remains of masonry, stone blocks and pillars adorned with carvings and bas-reliefs point to a people of superior civilization to the present day Assamese having inhabited this area. These may have been Kacharis, who are known to have occupied the Kapili valley up to the commencement of the 19th century.

With the exception of the Mīkīr Hills and the south-east of the Nowgong district, communications are good throughout the area under survey. In the Mīkīr Hills transport was entirely confined to coolies, the use of elephants being prohibited owing to the heavy clearing required to get them and their loads along the hill paths.

Supplies and labour were on the whole more easily obtained than in previous years. A portion of the Mīkīr Hills was found to be so sparsely inhabited that surveyors' squads had to be strengthened for line clearing, and arrangements made for sending them supplies.

The detail survey outturn of the party for the season amounted to 2,835 square miles on the 1-inch scale, 54 square miles of reserved forests surveyed on the 2-inch scale (including an area of 20 square miles special forest survey) and 22 square miles of special forest survey on the 4-inch scale. These outturns may be taken as satisfactory for the nature of the country, the major portion of which was covered with dense tree and grass jungle.

The survey cost-rates for the season are slightly higher than those for original and supplementary surveys in the previous year, and may be accounted for by the more difficult and jungly nature of the country.

The cost-rate for the special 4-inch forest survey is exceedingly high. This may be attributed to the following causes: —

1. Abnormally intricate ground, coupled with excessively dense jungle necessitating in places close on 500 fixings to the square mile in order to accurately map the features.
2. Heavy supervision charges distributed over a small establishment, and correspondingly small outturn.
3. Shortness of the field season owing to early rains.

Triangulation.—No triangulation was carried out during the season under report.

Traversing.—Extensive traversing has been run in the plains area to the north of the Brahmaputra river, in district Darrang, including a main traverse along the boundary of that district and the Akā and Dafla Hills, in which all existing pillars of Captain Cowan's survey of that boundary, seasons 1873—75, have been picked up and made stations of observation. In addition to the above a large number of traverses have been run in reserved forest areas for survey on the 2-inch and 4-inch scales.

During the season a total of 473 linear miles of traversing were run which includes 90 linear miles of special forest traverse. Selected stations to the number of 42 were permanently marked, and 273 zinc cylinders were also embedded.

The country under traverse resembled in every respect that surveyed in detail. The cost-rate for traversing is considerably higher than hitherto, but is accounted for by the difficult and densely wooded nature of the country, particularly along the Darrang-Daflā boundary, heavy supervision charges owing to there being no triangulation to bear a proportion of these, and the small outturns given by some of the new traversers who were unaccustomed to jungly country.

Recess duties.—The fair mapping of the season's detail outturn, comprising 11 complete one-inch sheets, has been carried out by 3 drawing sections under the supervision of Messrs. P. Ray, R. S. (4 sheets), E. M. Kenny (4 sheets) and P. C. Mitra (3 sheets). The progress of the fair mapping has been most satisfactory. Sheets 83 $\frac{B}{5, 12, 16}$ and 83 $\frac{F}{4}$ of the current work were submitted for publication before the close of the survey year, and the remaining 7 sheets will be completed before the party takes the field.

In addition to the above, sheets 78 $\frac{N}{10, 11, 15, 16}$, 83 $\frac{B}{2, 3, 6, 8}$, of season 1912-13 were submitted for publication during the year under report, making a total of 12 one-inch sheets.

The cost-rate for the fair mapping works out at 8·1 per square mile, which is slightly higher than that of the previous year.

The season's traverse computations have been completed, the work proving good.

ANDAMANS DETACHMENT.

BY LIEUTENANT-COLONEL C. L. ROBERTSON, C.M.G., R.E.

The programme of the detachment consisted in the execution of a special skeleton Forest survey on the scale of 2 inches = 1 mile in the Middle Island of the Andaman Islands.

PERSONNEL.

Provincial Officer.

Mr. E. Claudius in charge.

Lower Subordinate Service.

8 Surveyors, etc.

This survey was carried out in continuation of a similar survey which had been commenced in this locality during the previous field season by the Deputy Conservator of Forests, Port Blair, employing surveyors of the Survey of India deputed to the Forest Department for the purpose—an arrangement which, before the commencement of the year under report, it had been decided to abandon. It was undertaken at the request of the Forest Department for the purpose of obtaining an accurate survey of valuable areas of Padauk forest, which, for lack of trustworthy detailed surveys, it had hitherto been impossible to work.

For purposes of accounts and general control of the work the detachment was treated as part of the office of the Superintendent, Eastern Circle.

The country for survey was for the most part covered by low hills running down to the sea and cut up by valleys containing tidal creeks. It was densely wooded throughout, while nearly all tidal creeks contained mangrove swamps. It was entirely uninhabited and devoid of roads or paths of any sort, all supplies for the surveyors and their men having to be sent by boat or steam launch from Port Blair to the nearest point on the coast at which a landing could be effected.

The detachment left Shillong on 24th September 1913 and arrived at Port Blair on 2nd October 1913, the surveyors reaching their ground a few days later. Work was closed about 15th May 1914 and those of the personnel who did not proceed on leave arrived back in recess quarters in Shillong on 31st May 1914.

Though the discomforts of work in this locality, due to constant rain, dense forest, leeches and other insect pests, and precarious means of communication

and supply, were considerable, the health of the detachment was on the whole wonderfully good.

Topography.—Owing to the lack of sufficient triangulation it was found impossible to contour the ground with accuracy and the Forest Department therefore consented to accept an uncontoured map.

The position and lie of the hill features, however, have been shewn by form lines, and, where possible, heights have been given to hill tops.

Triangulation.—No triangulation was carried out by the detachment.

Traversing.—Two surveyors were employed on this during the season. Between them they completed the traversing of an area of 40 square miles part of which was utilized for current topographical work and part remains over for utilization next season. The length of theodolite chain traverse line was 18 linear miles and the rate per man per month of 14 working days works out to 13·5 miles.

The details of this traversing are given in Table II.

Recess duties.—The field sections were completed on return to recess quarters in Shillong and the traverse computations worked out. All field work was then sent to the Officer in charge Forest Map Office for the preparation by him of the maps for publication and the detachment was broken up, the members not on leave being transferred to the different parties of the Circle.

It is proposed to reform the detachment at the commencement of next field season, and it is hoped that the work for which the Forest Department have asked will be completed by the close of that season.

TABLE I.

OUTTURNS OF DETAIL SURVEY.

Scale.	Class of Survey.	Circle.	Party.	Locality.	Outturn.		Average number of fixings per square mile.	
					Total square miles.	Average per man per month, square miles.	*In situ* (by re-section).	Plane-table Traverse.
¼-inch	Revision Survey.	N	No. 1	Ladakh	869	434·5	0·2	...
½-inch	Survey	S	No. 6	Hyderābād	3,086	83·4	6·0	...
½-inch	Revision Survey.	N	No. 1	Ladākh	125	148·8	0·6	...
		E	No. 9	Bihār and Orissa	1,695	53·0	8·0	...
1-inch	Survey	N	No. 1	Kashmīr and North-West Frontier Province	2,652	31·0	7·1	...
		S	No. 5	Central Provinces and Berār	3,505	27·0	12·0	...
		S	No. 6	Berār	2,268	23·7	16·0	...
		S	No. 7	Madras	3,041	32·9	10·3 (a)	...
		S	No. 8	Madras	1,223	9·9	6·4	28·3
		E	No. 9	Bihār and Orissa	560	21·0	12·0	...
		E	No. 10	Upper Burma	4,024	38·2	4·0	8·0
		E	No. 11	Lower Burma	2,437	29·4	2·9	1·4
		E	No. 12	Assam	1,421	22·9	3·0	8·1
1-inch	Resurvey	N	No. 2	Punjab	1,514	...	...	...
		N	No. 3	Punjab and United Provinces.	84	28·6	13·0	...
		N	No. 4	United Provinces	4,726	26·1	12·0	...

(a) Including plane-table traverse fixings.

OUTTURNS OF DETAIL SURVEY—*contd.*

Scale.	Class of Survey.	Circle.	Party.	Locality.	OUTTURN. Total square miles.	OUTTURN. Average per man per month, square miles.	AVERAGE NUMBER OF FIXINGS PER SQUARE MILE. *In situ* (by re-section).	AVERAGE NUMBER OF FIXINGS PER SQUARE MILE. Plane-table Traverse.
1-inch .	Revision Survey.	N	No. 2	Punjab	5,190	44·6	14·0	...
		N	No. 3	Punjab and United Provinces.	6,118	28·6	13·0	...
		S	No. 5	Central Provinces and Berār	637	48·0	6·0	...
		E	No. 10	Upper Burma . .	587	28·9	5·0	5·0
		E	No. 11	Lower Burma . . .	62	62·0	1·2	...
		E	No. 12	Assam	66	31·3	2·2	6·2
1-inch .	Supplementary Survey.	N	No. 4	United Provinces . .	[illegible],314	41·3	20·0	...
		S	No. 7	Madras and Mysore . .	1,393	57·3	6·0 (*a*)	...
		E	No. 9	Bihār and Orissa . .	2,114	23·0	13·0	..
		E	No. 12	Assam	1,348	28·9	2·4	11·7
1½-inch	Survey	S	No. 8	Madras	343	5·8	3·6	59·0
2-inch .	Survey .	N	No. 1	Jammu and Environs .	33	8·7	33·3	...
		S	No. 6	Berār	171	8·8	36·0	...
		S	No. 7	Madras . . .	177	11·5	52·3 (*a*)	...
		E	No. 9	Bihār and Orissa .	11	...	79·0	...
		E	No. 10	Upper Burma . . .	92	11·7	10·0	53·0
		E	No. 11	Lower Burma . .	95	8·2	4·0	24·7
		E	No. 12	Assam	34	7·7	3·0	40·1
2-inch	Survey (Special forest.) .	E	No. 12	Assam	20	4·8	...	105·6
2-inch	Skeleton Survey uncontoured.	E	Andamans Detachment.	Andaman Islands . .	302	6·1	...	77·0
4-inch .	Survey (Special forest.) .	E	No. 12	Assam	22	1·4	...	425·9
8-inch .	Survey .	N	Simla Survey Detachment.	Simla	640	32·0	2·5	..
16-inch	Survey .	N	No. 20	Guna, Kamptee and Rājkot	20·34	0·68	...	...
36-inch	Survey .	N	No. 20	Sitābaldi Fort . . .	0·27	0·24	...	...
64-inch	Survey .	N	No. 20	Guna, Kamptee and Rājkot	0·82	0·07	...	...
125 feet to 1 inch.	Supplementary Survey.	N	Simla Survey Detachment.	Simla	*acres.* 2,418	*acres.* 30·9	...	*acres.* 4·5

(*a*) Including plane-table traverse fixings.

F 2

TABLE II.

DETAILS OF TRIANGULATION AND TRAVERSING.

Scale.	Class of survey.	Circle.	Party.	Locality.	Triangulation. Instrument used; diameter in inches.	Triangulation. Area in square miles.	Triangulation. Square miles to each point fixed.	Triangulation. Square miles to each height.	Triangulation. Stations fixed.	Triangulation. Triangular error in seconds.	Triangulation. Linear error per mile in feet.	Triangulation. Intersected Points. Number of points fixed.	Triangulation. Intersected Points. Linear error per mile in feet.	Traversing. Area in square miles.	Traversing. Linear miles of chaining.	Traversing. Number of stations at which theodolite was set up.	Traversing. Angular error per station in seconds.	Traversing. Linear error per 1,000.
1-inch	Triangulation	N	No. 1	Kashmīr	6	2,377 { 627	4·5	5·2	16	7·45	0·43	113	0·57	...	...	...	...	...
						1,750	...	...	..	...	not yet completed							
1-inch	Triangulation	N	No. 1	North-West Frontier Province.	6	300	4·6	4·6	4	1·74	0·41	59	0·89	...	...	...	...	...
1-inch	Traversing	N	No. 1	Punjab	6	...	...	...	...	...	...	...	...	...	98	129	9	2·22
1-inch	Triangulation	N	No. 2	Punjab	6	2,280	4·7	5·8	70	12·0	0·05	417	0·28	...	...	...	...	...
1-inch	Traversing	N	No. 2	Punjab	6	...	...	...	...	...	...	...	...	...	738·2	1,361	3·30	0·75
1-inch	Traversing	N	No. 3	United Provinces	...	...	...	...	...	...	...	...	...	1,333	1373·68	4,777	3	0·25
1-inch	Traversing	N	No. 4	United Provinces	...	...	...	...	...	..	...	...	...	...	196·2	538	·03	0·01
16-inch	Survey	N	No. 20	Guna, Kamptee, Rājkot and Sanāwar.	6	51·0	6	6	5	12	2	7	3	18·11	133·81	1,099	9	0·15
16-inch	Resurvey	N	No. 20	Meerut and Dehra Dūn	6	53·0	2	2	5	25	2	...	3	13·83	119·31	1,246	9	0·17
36-inch	Survey	N	No. 20	Sītābaldī Fort	5 and 6	0·50	...	...	..	...	...	...	...	0·25	4·11	62	7	0·25

125 feet to one inch.	Supplementary Survey.	N	Simla Survey Dett.	Simla	...	...	...	...	...	...	...	...	...	4·2	23·8	16·5	6	0·75
1-inch	Survey and Revision Survey.	S	No. 5	Central Provinces and Berār	6	4,796	7·0	7·0	182	12·0	0·28	747	0·73	...	...	...	...	...
½-inch and 1-inch.	Survey	S	No. 6	Hyderābād and Bombay	5 and 6	8,985	8·6	8·6	125	6·2	0·12	620	0·43	...	...	...	...	...
1-inch	Survey	S	No. 7	Madras and French Territory	6	5,226	3·9	3·9	93	7·2	0·10	1,205	0·51	...	...	...	...	...
1-inch and 1½-inch.	Survey	S	No. 8	Madras	6	1,005	3·4	3·4	19	8·5	0·24	437	1·03	(a)	55	551	9·3	0·85
½-inch, 1-inch and 2-inch.	Survey, Revision Survey and Supplementary Survey.	E	No. 9	Bengal and Bihār and Orissa	6	3,432	9·5	9·5	56	9	0·29	292	1·3	700	353	1,461	3	4
1-inch and 2-inch.	Survey and Revision Survey.	E	No. 10	Upper Burma	6	6,150	8·3	8·3	38	10	0·16	675	0·5	...	326	4,051	8·7	15
1-inch and 2-inch.	Survey and Revision Survey.	E	No. 11	Lower Burma	6	2,200	8·0	8·0	9	8	0·2	266	0·4	...	66·4	1,495	5	1·4
1-inch and 2-inch.	Survey, Revision Survey and Supplementary Survey.	E	No. 12	Assam	...	...	...	...	...	...	...	...	...	1,000	383	3,101	4·5	2·5
2-inch and 4-inch.	Special Forest Survey.	E	No. 12	Assam	...	...	...	...	...	...	...	...	...	100	90	1,212	2·4	4·1
2-inch	Special Forest Skeleton Survey.	E	Andamans Dett.	Andaman Islands	6	...	...	...	...	...	...	...	...	40	18	263	3·0	5·0

(a) Included in area given under Triangulation.

TABLE III.

COST-RATES OF SURVEY.

Circle.	Party.	Locality.	COST-RATES, RUPEES.																		Total survey outturns on all scales, square miles.	Total cost of party.	REMARKS.
			¼-inch revision survey.	½-inch survey.	½-inch revision survey.	1-inch survey.	1-inch revision survey.	1-inch re-survey.	1-inch supplementary survey.	1½-inch survey.	1½-inch revision survey.	2-inch survey.	4-inch survey.	16-inch survey.	36-inch survey.	64-inch resurvey.	Triangulation per square mile.	TRAVERSING PER LINEAR MILE. Topograph	TRAVERSING PER LINEAR MILE. Forest Boundary.	Fair mapping per square mile.			
			Per square mile.											Per acre.								Rs.	
N	No. 1	Kashmir and Punjab	0·9	...	9·0	19·2	..	...	...	...	...	38·4	...	...	...	...	6·2	14·6	...	5·3	3,679	1,10,403*	* Excludes Rs. 281 cost for work on Field Litho Press.
		North-West Frontier Province.	...	...	...	25·0	...	...	...	...	...	...	...	...	...	...	36·7	...	...	...			
N	No. 2	Punjab	...	...	...	...	9·67	9·12	...	...	...	...	...	...	...	...	5·55	8·23	...	3·3	6,704	1,06,122	
N	No. 3	Punjab and United Provinces.	..	..	...	...	10·46		...	...	...	...	...	...	...	...	...	14·2	...	4·7	6,202	1,13,222	
N	No. 4	United Provinces	...	...	...	...	...	9·2		...	...	..	...	...	...	...	...	27·8	...	3·8	7,040	97,637	
N	No. 20	Guna, Kamptee and Rājkot.	...	...	...	...	...	...	...	...	...	...	...	1·30	...	8·89	0·03†	0·39†	...	1·5	21·44	43,096	† These are per acre.
	"	Sītābaldi Fort	...	...	...	...	...	..	...	...	...	...	...		4·57	...	...	0·45†		..			

N	Simla Survey Detachment.	Simla . . .	...	...	...	...	...	...	...	...	..	...	...	...	...	...	...	23·7	...	·	3,058 acres.	29,433	No cost-rates for topography are available at present as the work is still incomplete.
S	No. 5	Central Provinces and Berār.	...	...	...	13·3	9·5	...	...	...	..	...	...	...	...	...	8·6	...	...	5·0	4,142	1,14,763	
S	No. 6	Berār, Hyderābād and Bombay.	...	3·6	...	9·7	...	...	...	...	...	34·8	..	...	...	...	2·9	...	...	4·2	5,525	89,513	
S	No. 7	Madras, Mysore and French Territory.	...	...	...	10·7	...	...	8·9	...		24·0	...	...	...	...	4·7	...	...	5·4	4,611	99,178	
S	No. 8	Madras . . .	...	...	...	46·7	...	...	...	55·4	...	...	...	...	...	...	17·8	67·3	...	16·3	1,566	1,27,462	
E	No. 9	Bengal and Bihār and Orissa.	...		6·5	24·5	...		14·7	...	...	64·5	...	...	...	..	2·2	8·4	25·9	(a) 6·8 (b) 1·8	4,380	1,04,649	(a) For 1-inch. (b) For ½-inch.
E	No. 10	Upper Burma . .	...	...	...	22·4	13·9	...	...	...	...	54·5	...	...	...	..	8·4	33·3	71·1	7·5	4,763	(c) 2,00,016	(c) Exclusive of Maymyo Drawing Office, Rs. 20,009.
E	No. 11	Lower Burma . .	...	...	...	40·3	8·4	...	...	...	...	93·4	...	...	...	...	7·2	...	52·8	6·7	2,594	(d) 1,45,896	(d) Excludes Rs. 3,506 for Forest Boundary Survey.
E	No. 12	Assam . . .	...	...	...	23·9	15·6	...	19·7	...	...	65·1 90·6 (A)	108·9 (B)	...	...	...	...	78·5	(e) 51·3	8·1	2,911	(f) 1,36,548	(A) Special Forest 2-inch Survey. (B) Special Forest 4-inch Survey. (e) Traversing for special 2-inch and 4-inch Forest Surveys. (f) Includes Rs. 17,516 expenditure on Special Forest Survey debitable to Forest Department.
E	Andamans Detachment.	Andaman Islands .	...	...	...	...	...	...	...	..	...	(g) 76·6	...	...	...	..	...	3·3	...	(h) Nil.	302	(i) 23,692	(g) Skeleton Survey (Uncontoured). (h) Mapping in Forest Map Office, Dehra Dūn. (i) Debitable to Forest Department.

PART II.—GEODETIC AND SCIENTIFIC OPERATIONS.

ASTRONOMICAL LATITUDES.

No. 13 Party.

(*Vide* Index Map No. 10).

By Captain V. R. Cotter, I.A.

Personnel.

Imperial Officer.
Captain V. R. Cotter, I.A., in charge.

Lower Subordinate Service.
3 Computers, etc.

During the season 1913-14 latitude observations were carried out along the meridian of 73° approximately, including stations both on the Bombay coast and on the Western Ghāts.

In addition observations were made at two stations near the foot of the Himālayas; at one in the foot-hills and at one about 20 miles away from the plains, in the Himālayas.

The selection of the Bombay coast was due partly to certain observations made at Alibāg by the Director of the Government Observatory, Colāba, which pointed to an excess of density of the earth's crust in that neighbourhood. This will be touched on later.

The four stations in the region of the Himālayas filled in a gap where observations were scarce; it was hoped that their inclusion might throw additional light on the conditions causing the tenuity of matter at the foot of the Himālayas.

The instrument used was Zenith Telescope No. 1 by T. Cooke & Sons. Owing to an accident all the wires of the eyepiece micrometer had to be replaced before starting work. The re-wiring was not found entirely satisfactory. The excessive heat and moisture of the Bombay coast appeared to cause a "sag" in the spider webs, but fortunately this was noticed and the intervals between micrometer wires A, B, and C were measured many times so that changes could be traced and the effect on the observations minimised. It should be noted here that a "sag" of about $\frac{1}{6000}$ of an inch causes a difference of 1 division in the micrometer scale, so that only a very minute alteration was necessary to become noticeable. A new set of wires has since been fixed in the eyepiece micrometer.

The movable diaphragm holding the micrometer wires A, B and C was found to stick at certain temperatures and this has since been rectified by slightly grinding it down.

The glow lamps supplied by the makers for illumination purposes were not found satisfactory as they were of insufficient candle power. New glow lamps of a better pattern have since been purchased and have worked very satisfactorily.

Determinations of the value of 1 division of the level scales were made at the beginning and end of the field season.

They gave the following results :—

	Before field season.	After field season.
	"	"
Level No. 1 value of 1 division . . .	0·914	0·918
" " 4 " " . . .	0·969	0·958

The means of these values were adopted, *viz.* :—

	"
Level No. 1	0·916
" " 4	0·963

The micrometer value was obtained by observations of 130 couples of stars. The result was satisfactory, the value of 1 revolution of the micrometer head being determined as 50″·072 with a probable error of $\pm$0″·0032.

The results of the season's observations are shown in the following table:—

STATION.	Mean Co-latitude EW.	Mean Co-latitude WE.	Difference EW − WE.	Mean Co-latitude from observations giving + ve. micrometer corrections $=C_+$.	Mean + ve. micrometer correction $=M_+$.	Mean Co-latitude from observations giving − ve. micrometer correction $=C_-$.	Mean − ve. micrometer correction $=M_-$.	Apparent error of micrometer value $\frac{C_+ - C_-}{M_+ + M_-}$.	p. e. of unit weight.
	"	"	"	"		"		"	"
Pārnera	10·40	10·18	+0·22	9·85	3609	10·35	2392	−0·000083	±0·286
Karanja	46·50	46·18	+0·32	45·80	3632	46·53	3144	−0·000108	±0·303
Alibāg	33·87	34·25	−0·38	33·19	2854	34·08	2801	−0·000157	±0·344
Mirya	30·26	30·40	−0·14	30·21	4528	30·43	2954	−0·000029	±0·230
Kumbhāri	55·49	55·81	−0·32	55·52	2762	55·68	2657	−0·000030	±0·337
Chaukola	34·99	34·97	+0·02	34·91	2689	35·05	2563	−0·000026	±0·368
Mahābaleshwar	49·84	50·08	−0·24	49·77	3833	50·10	3146	−0·000047	±0·272
Mira Dongar	3·93	4·09	−0·16	4·05	2863	3·86	3249	+0·000034	±0·323
Kalsūbai	1·54	1·95	−0·41	1·65	3012	2·12	2137	−0·000091	±0·260
Godhna	51·36	51·13	+0·23	51·09	2764	51·41	3311	−0·000053	±0·220
Mehesarī	51·78	51·75	+0·03	51·52	2723	52·12	3496	−0·000096	±0·327
Rānīgarh	24·84	24·90	−0·06	24·52	3604	25·21	3409	−0·000098	±0·409
Harpālsid	37·71	37·75	−0·04	37·47	3760	37·92	3124	−0·000065	±0·245
Kankeshvar	42·13	42·03	+0·10	42·00	2745	42·15	3080	−0·000026	±0·196

The deflections of the plumb line are shown in the following table :—

Station.	Height.	Number of stars.	Number of observations.	Longitude.	Geodetic Latitude.	Seconds of Astronomical Latitude.	P. E.	Deflection A−G.
	Feet.			° ′	° ′ ″	″	″	″
Pārnera	614	53	64	72 59	20 32 56·85	49·83	±0·057	— 7·02
Karanja	997	59	67	72 59	18 51 24·99	13·79	±0·057	—11·20
Alibāg	10	51	56	72 52	18 38 36·69	26·35	±0·070	—10·34
Mirya	473	50	56	73 18	17 1 35·92	29·65	±0·047	— 6·27
Kumbhāri	2,898	54	55	74 20	15 9 1·80	4·31	±0·068	+ ·251
Chaukola	2,794	59	102	73 59	15 55 31·44	24·94	±0·065	— 6·50
Mahābleshwar	4,719	59	68	73 43	17 55 15·55	9·91	±0·052	— 5·64
Mira Dongar	1,863	61	72	73 12	18 41 1·68	55·97	±0·060	— 5·71
Kalsūbai	5,400	48	55	73 45	19 36 1·76	57·89	±0·055	— 3·87
Godhna	846	42	38	77 57	29 37 18·46	8·73	±0·052	— 9·73
Mehesaii	811	48	53	78 11	29 30 18·21	8·18	±0·068	—10·03
Rānīgarh	7,055	52	51	78 43	30 4 4·47	34·80	±0·084	—29·67
Harpālsid	1,000†	52	50	78 36	29 39 50·90	22·24	±0·051	−28·60
			* Seconda	ry station.				
Kankeshvar	1,260	48	56	72 58	18 44	17·89	±0·041	...

* The Geodetic Latitude of the Latitude Pillar at Kankeshvar, h. s. is being redetermined, there being some uncertainty as to its position owing to the old secondary station having partially disappeared.

† This is the height of the Latitude Pillar and not of the G. T. Station.

Descriptions of the Stations.—*With special reference to the existence of local causes of plumb line deflection.*

Pārnera, H. S.—Is situated on a hill which rises out of the flat plains. There is a very slight excess of surface mass on the north of this hill, but not sufficient to cause a deflection of one second.

Karanja, H. S.—Is situated on an island near Bombay. The hill on which it is situated has an excess of mass to the north of the station; to the south it is cut off in a sharp cliff which descends almost vertically to the sea.

Kankeshvar, h. s.—Is a secondary station. There is a slight excess of visible mass to the north, taking into consideration only those hills within 2 miles of the station.

Alibāg.—The latitude of a temporary station was determined by 15 Party in the season 1912-13. This station was not found existing in 1913. The latitude of this station was 18°–38′–36″·59 and its longitude 72°–52′–12″·22. Before its disappearance its position relative to Alibāg Observatory transit was measured by the Director of the Observatory, and the deduced geodetic co-ordinates of Alibāg Observatory transit were found to be: Latitude 18°–38′–36″·69, Longitude 72°–52′–12″·42. This value of the latitude has been used in computing the plumb line deflection. The country in the immediate vicinity is quite flat.

Mirya, H. S.—The hill on which Mirya, H. S. is situated has a slight excess of mass to the north.

Kumbhāri, H. S.—Is on the top of a very inaccessible hill and a path had to be cut to it through the jungle from the village of Keloli, for a distance of 2½ miles. A northerly deflection was expected, but the observations show southerly deflection. There is no marked excess of surface masses either north or south.

Chaukola, H. S.—Within a radius of 1 mile there is slight excess of surface mass to the south, but probably not enough to affect the deflection by 1 second.

Mahābaleshwar, H. S.—The hill on which Mahābaleshwar, H. S is situated is near the western edge of the Western Ghats. The ground falls away very steeply about a mile to the west of the station, but there is no marked excess of surface masses on the meridian in either direction.

Mira Dongar, H. S.—The hill on which Mira Dongar, H. S is situated is one of a large number, all about the same height, in that locality. There is no marked excess of surface masses either to the north or the south.

Kalsūbai Hill.—Rises very sharply out of the surrounding hills which it greatly exceeds in height. There is no marked excess of surface masses on the meridian in either direction.

Godhna, T. S.—The Tower station is situated in the plains, far away from the hills. No local cause of plumb line deflection is visible.

Mehesarī, T. S.—The Tower station is in the plains, there are no hills in the vicinity, and no local cause of plumb line deflection is visible.

Rānīgarh, H. S.—The Trigonometrical station is in the Himalayas. There is no marked local excess of hills to the north or the south on the meridian.

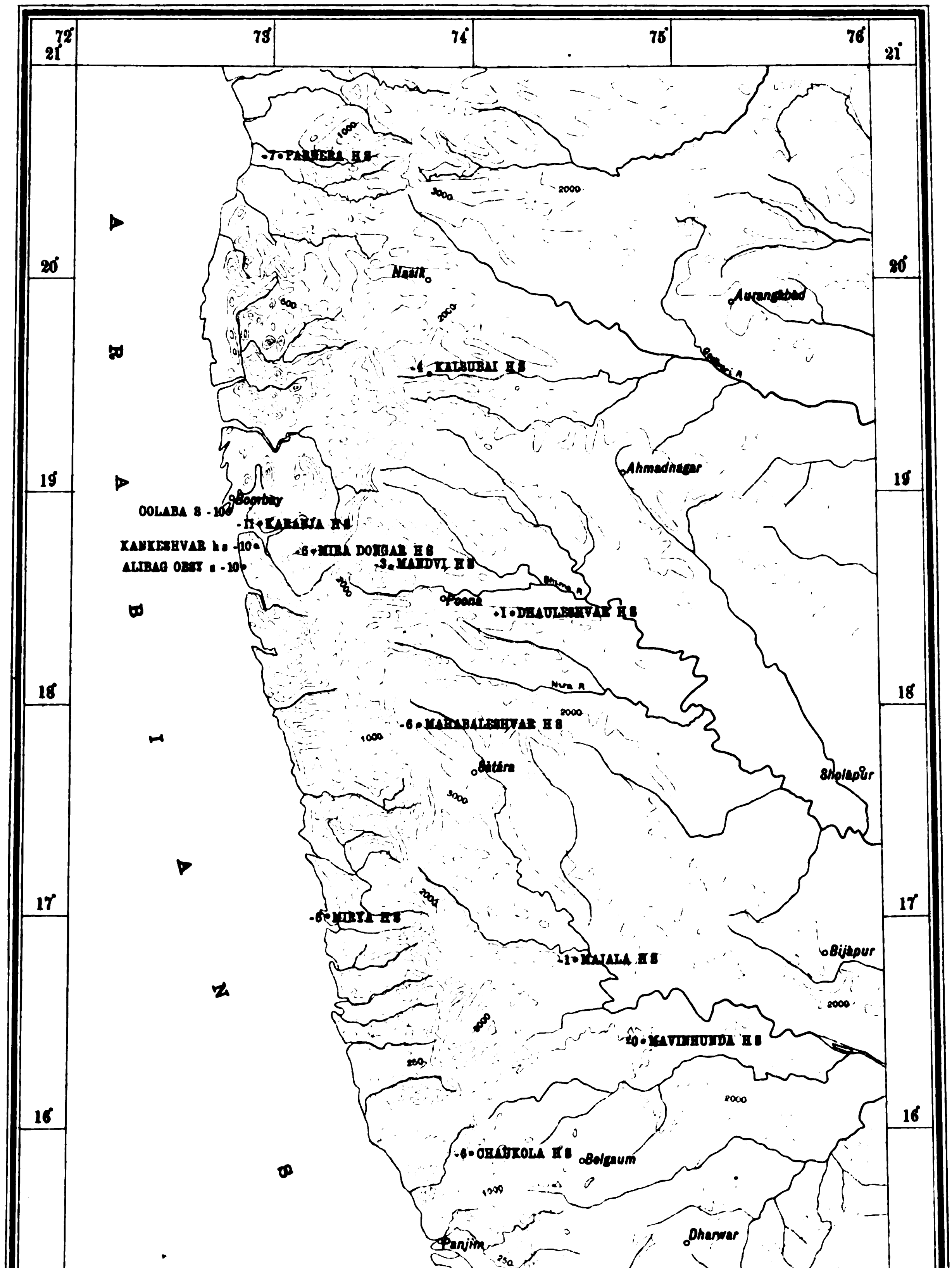
Harpālsid, H. S.—Is situated on the edge of the Himālayan foot-hills and there is no marked local excess of visible masses on the meridian on the north or the south.

Discussion of Results.

The area round Bombay shows curious results as regards deflections of the plumb-line in the meridian.

A glance at sketch map will show the information available. In addition to these deflections we know that the deflection in the prime vertical at Colāba is 7 seconds West.

PLUMB LINE DEFLECTIONS ON THE WEST COAST AND NEIGHBOURHOOD



Rec. No. 934 D. D. 1918—S. I.—550

Helioxincographed at the Survey of India Offices, Dehra Dun.

Scale 1 Inch = 48 Miles

There is nothing in the topography around Colāba to account for such a large northerly deflection as 10 seconds, or for such a large westerly deflection as 7 seconds.

If we assume Hayford's theory to be correct, that is to say, that isostatic compensation is complete, the deflections in the meridian at the stations around Bombay, to the nearest second, are found by computation to be:—

Colāba	*Nil.*
Karanja	*Nil.*
Alibāg	*Nil.*
Mira Dongar	+1″.
Māndvi	−1″.

The wide divergence between these values and the results of the observations points to the deflections around Bombay being anomalous and to their being caused by some hidden local attraction or repulsion.

From the evidence of the deflections above we would therefore look for either (1) an area of excessive density somewhere north of Colāba or (2) an area of deficient density somewhere south of Alibāg.

But we have additional evidence from the Pendulum observations. The force of gravity has been found to be a little in excess at Colāba but very greatly in defect at Alibāg. This leads us to believe that the anomaly of the deflections is caused by a region of deficient density near Alibāg rather than by an excess of density north of Colāba, because it would be possible to have a line of deficient density in the earth's crust in that region which would account for the observed anomalies, whereas no solution appears possible on the assumption of an area of excessive density north of Colāba.

The above is merely conjecture. Further pendulum observations must be awaited before any more certain deductions can be made.

The deflection at Kumbhāri is worthy of note, being 2 seconds south. This station lies in a line between Chaukola (−6) and Karamur (−5) and the deflection thus appears anomalous. This being hilly country, until the attractions of the topographical features have been computed and Hayford's corrections applied, no definite opinion can be passed on the deflection. As regards the stations near the Himālayan foot-hills, the outstanding feature is the difference in the plumb line deflections at Mehesari (—10) and Harpālsid (—29). In this we have another instance of the effect of the tenuity of the matter at the foot of the Himālayas, and the difference in the deflection, 19 seconds, affords a most striking example of the abnormal condition of the earth's crust in those regions. The distance between these stations is 26 miles. Harpālsid is on the fringe of the mountains, Mehesari about 24 miles from their foot, measured along a line at right angles to their general direction.

PENDULUM OPERATIONS.

No. 14 PARTY.

(*Vide* Index Map No. 10).

BY CAPTAIN G. F. T. OAKES, R.E.

During the season 1913-14 pendulum observations were made at 10 stations along a line extending from Alibāg to Pāli (Mārwār). Observations were made in 1904 at Colāba, Bombay, which lies between the two first stations of Alībāg and Damān, and therefore this station has been included for the sake of comparison in the summary of results of the season's work, given in Table VII. A list of the stations will be found in this table.

PERSONNEL.

Imperial Officers.

Captain H. J. Couchman, R.E., in charge up to 27th April 1914.
Captain G. F. T. Oakes, R.E., in charge from 28th April to 8th September 1914, attached from 9th September 1914.

Provincial Officers.

Mr. O. N. Pushong, up to 9th November 1913.
„ C. S. McInnes, from 1st November 1913 till proceeding on leave on 4th May 1914.

Lower Subordinate Service.

4 Computers, etc.

Alibāg and Damān are coastal stations. Surat, Broach, Baroda and Ahmadābād are on the plains between the coast and

the western limits of the Central Indian Plateau. Abu is on the highest part of the Arāvalli Hills, while Deesa, Erinpura and Pāli are on the plains near and to the west of the Arāvallis. The immediate surroundings of all the stations are flat, except in the case of Abu. This is on an isolated block of hills, which cover an area of about 18 miles by 7. The highest point is about 5,500 feet, but the hills round the pendulum station only run up to between 4,000 and 4,500 feet.

All the pendulum observations of the season were carried out by Captain Couchman, with the exception of a few of those at Dehra Dūn in March, which were made by Captain Oakes.

Thanks to the kindness of the local officials good observing rooms were usually available. The hourly changes in temperature were smaller than in previous years and are shown in Table I.

TABLE I.

Temperatures.

STATIONS.	NIGHT.		DAY.		MEAN.	
	Average temperature.	Hourly Change.	Average temperature.	Hourly Change.	Average temperature.	Hourly Change.
	°C	°C	°C	°C	°C	°C
Dehra Dūn . . Nov. and Dec. 1913.	15·82	+0·09	15·83	+0·06	15·82	+0·07
Alibāg	24·01	+0·04	23·34	+0·13	23·68	+0·08
Damān	24·17	+0·03	23·39	+0·04	23·78	+0·03
Surat	25·38	—0·01	23·79	+0·13	24·59	+0·06
Broach	23·96	+0·03	22·86	+0·04	23·41	+0·03
Baroda	23·92	—0·09	22·22	+0·17	23·07	+0·04
Ahmadābād	22·98	+0·05	22·66	+0·03	22·82	+0·04
Deesa	20·07	—0·12	18·04	+0·30	19·06	+0·09
Abu	14·46	+0·01	13·50	+0·13	13·98	+0·07
Erinpura	22·32	—0·23	20·11	+0·53	21·22	+0·15
Pāli, Mārwār	24·26	+0·12	24·15	+0·05	24·20	+0·08
Dehra Dūn . . March 1914	17·73	+0·15	17·93	+0·06	17·83	+0·11

Observations for the *flexure* of the stand were made at the commencement and close of work at each station, two sets being taken as a rule. The following table shows the mean values before and after work and the adopted values.

TABLE II.

Flexure.

STATION.	Date.	Observed Flexure.	Differences.	Adopted Flexure.
		10^{-7} Sec.	10^{-7} Sec.	10^{-7} Sec.
Dehra Dūn	November 1913 .	42·8	...	...
	1st December 1913 .	42·4	0·4	43 (1st series)
	6th ,, ,, .	41·0	1·4	42 (2nd series)

TABLE II—*concld.*

Flexure—*concld.*

STATION.	Date.	Observed Flexure.	Differences.	Adopted Flexure.
		10^{-7} Sec.	10^{-7} Sec.	10^{-7} Sec.
Alibāg	26th December 1913 .	57·6	...	...
	30th „ „ .	59·0	1·4	58
Damān	4th January 1914 .	49·4	...	...
	8th „ „ .	48·2	1·2	49
Surat	12th January 1914 .	52·1	...	...
	16th „ „ .	53·3	1·2	53
Broach	19th January 1914 .	51·4	...	...
	23rd „ „ .	49·5	1·9	50
Baroda	26th January 1914	49·5	...	...
	30th „ „ .	51·0	1·5	50
Ahmadābād	2nd February 1914 .	41·5	...	...
	6th „ „ .	43·2	1·7	42
Deesa	9th February 1914 .	43·2	...	...
	13th „ „ .	43·9	0·7	44
Abu	17th February 1914 .	54·4	...	...
	21st „ „ ...	53·0	1·4	54
Erinpura	24th February 1914 .	48·6	...	...
	28th „ „ .	48·1	0·5	48
Pāli, Mārwār . . .	3rd March 1914 .	47·3	...	...
	7th „ „ .	47·1	0·2	47
Dehra Dūn	15th March 1914 .	44·0	...	...
	19th „ „ .	42·5	1·5	43

The clock rate was determined by Mr. C. S. McInnes. For some time past the behaviour of the clock (No. 238 by Strasser and Rohde) has been a source of disquiet, and it has now been decided to supplement the equipment with a break-circuit chronometer as soon as one can be obtained. This conclusion was arrived at after the fine performance of the chronometer in the possession of the de Filippi Expedition had been seen. The chronometer in question was one made by Poole.

The mean p. e. of a clock rate, determined from observations on two successive nights, was $\pm$ 0·025 second, and the mean p. e. of the rate derived from observations to one star on two successive nights was $\pm$ 0·090 second. These probable errors are higher than usual, owing no doubt partly to the fact that the observer was inexperienced but partly also to the increasing fallibility of the clock. The corresponding error in the mean time of vibration is only $\pm 1{\cdot}5 \times 10^{-7}$ second.

This season a new method of swinging the pendulums was employed. It was thought that better results might be obtained by swinging only one pendulum instead of four, the advantage being that the cover enclosing the pendulum stand would not need to be opened at all during the observations, thus ensuring a more steady temperature. Therefore on the first two days observations were made as before with all four pendulums, in order to see that no alteration in length had taken place, and then during the last two days No. 138 alone was observed. It was swung twice each night and twice each morning, each time a set of twenty 120 coincidence periods being taken, in place of the usual twelve sets of 60 coincidence periods. An examination of the results of this method proves interesting.

In table III is shown the difference in time of vibration of each swing from the mean at the station, in the case of the single pendulum.

TABLE III.

Differences in observed times of Vibration of the Pendulum No. 138.

Station.	Date.	Differences of each Swing from mean at the Station in 10^{-7} secs.									
		First day.				Second day.				Third day.	
		Night.	Night.	Day.	Day.	Night.	Night.	Day.	Day.	Night.	Day.
Dehra Dūn	Dec. 3-5	− 9	−63*	+ 20	+ 16	− 9	−10	+ 37	+ 16	...	...
Alibāg	,, 28-30	+ 4	+ 20	−18	−25	− 1	+ 22	− 8	+ 7	..	...
Damān	Jany. 6-8	+ 7	+ 4	−13	+ 16	+ 1	− 3	−14	+ 9	...	...
Surat	,, 14-16	+ 17	− 2	−16	− 7	+ 25	+ 16	−15	−21	...	.
Broach	,, 21-23	+ 12	+ 2	−35	−24	± 0	± 0	+ 13	+ 27	...	...
Baroda	,, 28-30	− 1	+ 19	−21	± 0	+ 7	+ 9	−18	+ 2	...	...
Ahmadābād	Feb. 4-6	−18	−17	+ 2	+ 22	+ 23	+ 36	−25	−24	...	...
Deesa	,, 11-13	−50	+ 12	+ 8	+ 54	−10	−12	− 2	± 0	...	...
Abu	,, 19-21	−31	+ 14	+ 4	+ 31	+ 14	−29	+ 4	− 5	...	...
Erinpura	,, 26-28	+ 85	+ 62	−83	−44	+ 60	+ 38	−92	−27	...	...
Pāli, Mārwār	March 5-7	−32	− 7	−11	− 4	+ 9	+ 16	− 2	+ 34	...	...
Dehra Dūn	,, 17-20	− 3	+ 12	− 9	−27	− 7	+ 17	+ 18	+ 4	+ 9	−14

Probable error of single observation: Night ±17·6. Day ±18·2.

Algebraical sum of apparent errors: Night +253. Day — 260.

Mean: Night + 5. Day — 5.

Algebraical sum of apparent errors. First Swings — 188. Second Swings + 181.

Mean = — 4. + 4.

*Rejected in Computation of mean time of Vibration.

From this table it appears,—

(*i*) that the night observations are not any more discrepant than the day ones, as had been suspected, but rather the reverse;

(*ii*) that the night values of the time of vibration are on the average larger than those of the day, thus indicating that at night the clock goes slightly faster than during the day;

(*iii*) that the first swings give on the average smaller values for the time of vibration than the second swings, which appears to indicate that the rate of the clock increases during the period of observation.

Table IV shows the apparent and probable errors of the mean and single pendulums.

TABLE IV.

Apparent and Probable Errors of Pendulums.

Station.	Date.	Differences between Individual and Mean Pendulums in 10^{-7} Secs.								Single Pendulum (No. 138) Differences between each pair and mean at the Station in 10^{-7} Secs.	
		137	V	138	V	139	V	140	V	First pair.	Second pair.
Dehra Dūn .	Nov. 1st day .	+86	+4	+2462	−4	−881	−23	...	...	...	...
	2nd day .	...	...	+2483	+17	−913	+9	−1653	+9	...	...
	3rd day .	+72	−10	...	...	−903	−1	−1632	−12	...	...
	4th day .	+74	−8	+2461	−5	...	...	−1653	+9	...	...
	Dec. 1st day .	+94	+12	+2485	+19	−902	−2	−1659	+15	+6	−24
	2nd day .	+69	−13	+2461	−5	−898	−6	−1646	+2	+14	+3
Alibāg . .	Dec. 1st day .	+85	+3	+2483	+17	−912	+8	−1646	+2	−7	−4
	2nd day .	+80	−2	+2456	−10	−901	−3	−1643	−1	−4	+14
Damān . .	Jan. 1st day .	+77	−5	+2478	+12	−896	−8	−1644	±0	−3	+10
	2nd day .	+84	+2	+2457	−9	−904	±0	−1649	+5	−6	±0
Surat . .	Jan. 1st day .	+114	+32	+2392	−74	−875	−29	−1624	−20	+1	−5
	2nd day .	+93	+11	+2452	−14	−903	−1	−1648	+4	+5	−2
Broach . .	Jan. 1st day .	+83	+1	+2473	+7	−911	+7	−1645	+1	−12	−11
	2nd day .	+75	−7	+2465	−1	−898	−6	−1641	−3	+7	+14
Baroda . .	Jan. 1st day .	+64	−18	+2487	+21	−910	+6	−1645	+1	−11	+10
	2nd day .	+96	+14	+2465	−1	−916	+12	−1643	−1	−5	+5
Ahmadābād .	Feb. 1st day .	+68	−14	+2463	−3	−926	+22	−1634	−10	−8	+2
	2nd day .	+88	+6	+2478	+12	−901	−3	−1637	−7	−1	+6
Deesa . .	Feb. 1st day .	+83	+1	+2445	−21	−911	+7	−1655	+11	−21	+33
	2nd day .	+77	−5	+2478	+12	−890	−14	−1631	−13	−6	−6
Abu . .	Feb. 1st day .	+75	−7	+2466	±0	−934	+30	−1634	−10	−13	+22
	2nd day .	+98	+16	+2479	+13	−900	−4	−1650	+6	+9	−17
Erinpura .	Feb. 1st day .	+120	+38	+2458	−8	−897	−7	−1659	+15	+1	+9
	2nd day .	+77	−5	+2442	−24	−891	−13	−1647	+3	−16	+6
Pāli Mārwār .	Mar. 1st day .	+100	+18	+2481	+15	−913	+9	−1639	−5	−21	−6
	2nd day .	+74	−8	+2472	+6	−924	+20	−1649	+5	+4	+25
Dehra Dūn .	Mar. 1st day .	+53	−29	+2475	+9	−899	−5	−1630	−14	−6	−8
	2nd day .	+66	−16	+2479	+13	−889	−15	−1651	+7	+6	+10
	3rd day .	...	...	...	...	...	...	...	...	−3	...
Means .		+82	...	+2466	...	−904	...	−1644	...	..	...

Probable error of single observation: Mean Pendulum ± 9·7. Single Pendulum ± 7·9.

It will be seen that the probable error of a single observation of the mean pendulum for the whole season is $\pm 9{\cdot}7 \times 10^{-7}$ second while that for the single pendulum is $\pm 7{\cdot}9 \times 10^{-7}$ second. Though these are not exactly comparable, it appears that no increase of accuracy is obtained by the single pendulum method and in future the former system will be reverted to, in which four sets, each consisting of a night and a day swing, will be taken with each of the four pendulums.

The times of vibration of the pendulums at Dehra Dūn are given in Table V.

TABLE V.

Times of Vibration of Pendulums at Dehra Dūn.

DATE.	137	138	139	140	Mean.	Single Pendulum No. 138.	Mean of single and Mean Pendulum.
1913	Sec.	Sec.	Sec.	Sec.	Sec.	Sec.	Sec.
Nov. 24—25	0·5072601	0·5074977	0·5071634	..			
25—26	...	4998	1602	0·5070862	0·5072515		
26—27	2587	...	1612	0883			
27—28	2589	4976	...	0862			
Dec. 1—2	2630	5021	1634	0877	2540		
2—3	2605	4997	1638	0890	2533		
Dec. 3—4	...	...	...	...	...	0·5074975	
4—5	...	...	...	...	...	4979	
Means	0·5072602	0·5074994	0·5071624	0·5070875	0·5072524	0·5074977	0·5073751
1914 March 15—16	0·5072555	0·5074977	0·5071603	0·5070872	0·5072502		
16—17	2568	4981	1613	0851	2503		
March 17—18	...	...	...	...	...	0·5074974	
18—19	...	...	...	...	...	4989	
Means	0·5072561	0·5074979	0·5071608	0·5070861	0·5072502	0·5074981	0·5073742
General Mean	0·5072582	0·5074987	0·5071616	0·5070868	0·5072513	0·5074979	
Difference March—Nov. and December.	—41	—15	—16	—14	—22	+4	—9
Value adopted	...	...	...	...	...	...	0·5073746

On completing the observations at Dehra Dūn at the end of the season it was found that the time of vibration of the mean pendulum obtained in March 1914 differed from that obtained in December 1913 by 24×10^{-7} second. A very careful examination of the records of the observations and the computations failed to disclose the cause of this discrepancy.

It will be noted from the table that the largest apparent change was in pendulum No. 137, but there is nothing to show that this change was a real one, or when it happened, as will be seen on examining Table IV. This table gives no indications of any of the pendulums changing its length.

It so happened that a set of observations had been taken in November just before the commencement of the December set, in which the pendulums had been swung in a different manner. Three pendulums had been swung at night; next morning the fourth had been swung twice and the other three once again. By accepting the night and day observations which balanced each other, another set of three values of the time of vibration of the mean pendulum was obtained, giving a mean value of 0·5072515 second. This falls between the December

value of 0·5072536 and the March value of 0·5072502, and it was decided to adopt the mean of the 5 sets in November and December as the value at the beginning of the season.

The mean of the single-pendulum and mean-pendulum values was adopted for the season's work.

In table VI is given the mean time of vibration at each field station, with the value of g deduced therefrom. The value of g at Dehra Dūn has as usual, been taken as 979·063 cm/sec².

TABLE VI.

Observed Values of g.

STATION.	Time of Vibration.	Difference from Dehra Dūn.	Observed Value of g.
	Seconds.		cm/sec².
Dehra Dūn	0·5073746	...	979·063
Alibāg	5074	+1328	978·551
Damān	4688	+ 942	978·700
Surat	4618	+ 872	978·727
Broach	4584	+ 838	978·740
Baroda	4560	+ 814	978·749
Ahmadābād	4335	+ 589	978·836
Deesa	4168	+ 422	978·900
Abu	4742	+ 996	978·679
Erinpura	4179	+ 433	978·896
Pāli Mārwār	4040	+ 294	978·950

TABLE VII.

Summary of Results, 1913-14.

Station.	Latitude.	Longitude.	Height above M. S. L.	Corrections: for Height.	Corrections: Bouguer.	Corrections: Hayford.	γ_0	γ_A (free air.)	γ_B (Bouguer.)	γ_C (Hayford.)	g	$g-\gamma_A$	$g-\gamma_B$	$g-\gamma_C$
	° ′ ″	° ′ ″	Feet.	cm.	cm.	cm.	cm.	cm.	cm.	cm.	cm	cm.	cm.	cm.
Alibāg	18 38 30	72 52 10	12	—·001	+·000	—·002	978·557	978·556	978·556	978·554	978·551	—·005	—·005	—·008
*Colāba**	*18 53 47*	*72 48 47*	*34*	*—·003*	*+·001*	*+·000*	*·571*	*·568*	*·569*	*·568*	*·631*	*+·063*	*+·062*	*+0·63*
Damān	20 24 45	72 50 05	15	—·001	+·000	—·006	·658	·657	·657	·651	·700	+·043	+·043	+·049
Surat	21 10 05	72 48 05	30	—·003	+·001	—·005	·703	·700	·701	·695	·727	+·027	+·026	+·032
Broach	21 42 05	72 59 00	51	—·005	+·002	—·006	·736	·731	·733	·725	·740	+·009	+·007	+·015
Baroda	22 18 35	73 11 05	109	—·010	+·004	—·007	·774	·764	·768	·757	·749	—·015	—·019	—·008
Ahmadābād	23 01 20	72 33 55	156	—·015	+·005	—·005	·820	·805	·810	·800	·836	+·031	+·026	+·036
Deesa	24 15 20	72 11 30	465	—·044	+·016	—·004	·901	·857	·873	·853	·900	+·043	+·027	+·047
Abu	24 35 40	72 43 00	3836	—·359	+·122†	+·085	·924	·565	·687	·650	·679	+·114	—·008	+·029
Erinpura	25 08 55	73 03 35	872	—·082	+·029	—·007	·962	·880	●·909	·873	·896	+·016	—·013	+·023
Pāli Mārwār	25 47 30	73 19 25	719	—·067	+·024	—·010	979·007	978·940	978·964	978·930	978·950	+·010	—·014	+·020

* Observations made in 1904.

$\gamma_0 = 978{\cdot}030\ (1 + 0{\cdot}005302 \sin^2\phi - 0{\cdot}000007 \sin^2 2\phi)$

† Includes orographical correction of —·007.

The summary of the results of the season's work is given in Table VII.

The chief point of note in these results is the great change in the force of gravity between Alibāg and Colāba. The change in $g-\gamma_B$ is 0·067 cm. and in $g-\gamma_C$ 0·066 cm. These stations are both on the coast only some 18 miles apart, and there is nothing in the topography of the surrounding country to account for this large change. The latitude observations in the neighbourhood show a constant northerly deflection of the plumb-line of about 10″, the deflections at both Colāba and Alibāg being actually 10″. No such rapid change in gravity has been observed anywhere else in India, and it has been decided to carry out further observations at the next opportunity.

The preponderance of positive residuals will also be noted. It was anticipated from the previously observed plumb-line deflections that an excess of gravity would be found. Chart II in the narrative report of No. 22 Party (Astronomical) (now No. 13) for the year 1907-08 shows what the deflections indicated; the pendulum results support the conclusion then arrived at.

Bouguer residuals at coast stations tend to be positive, but it was anticipated that with the assumption of ocean compensation these residuals would be reduced. We find, however, that allowing for compensation has little effect on the residuals at these stations on or near the West Coast. This is no doubt due to the gradual slope of the ocean bed and to the effect of the compensation under the sea being counteracted by that under the Western Ghāts.

In his professional paper on recent pendulum work, now in the press, Captain Couchman groups the pendulum stations in India into six classes and shows the changes effected in the residual $(g-\gamma)$ when compensation on the Hayford hypothesis is allowed for, *vide* Table VIII. He found that for all the stations, for which both the Bouguer and Hayford residuals had been already computed, the mean value of $g-\gamma_B$ was $-0·049$ and of $g-\gamma_C$ $+0·004$. He alters the equatorial constant in the formula for γ_0 in each case by these amounts, so as to make the mean residual in each series zero, and uses these revised values in his table.

TABLE VIII.

Changes effected in $g-\gamma$ by allowing for compensation.

Class of stations.	Mean $g-\gamma_B+·049$.	Mean $g-\gamma_C-·004$.	Change.
	cm.	cm.	cm.
Class I. Mountain Stations	—·058	+·013	+·071
Ditto. Neglecting Yercaud which is a detached hill mass.	—·070	+·026	+·096
Class II. Stations near foot of mountains . .	—·089	—·036	+·053
Class III. Stations within 100 miles of mountains.	—·018	—·020	—·002
Class IV. Plains of North India and Bengal .	—·014	—·003	—·017
Class V. Stations in or near the Central Indian Highlands.	+·021	+·011	—·010

TABLE IX.

Changes effected in $g-\gamma$ by allowing for compensation.

Station.	Height.	$g-\gamma_B$ + ·049.	$g-\gamma_C$ —·004.	Change.
Stations on the Coast.	Feet.	cm.	cm.	cm.
Cuttack	*92*	*+·052*	*+·002*	*—·050*
Madras	*20*	*+·035*	*—·057*	*—·092*
Colāba	*34*	*+·111*	*+·059*	*—·052*
Alibāg	12	+·044	—·007	—·051
Damān	15	+·092	+·045	—·047
			Mean	—·058
Stations near the Coast.				
Surat	30	+·075	+·028	—·047
Broach	51	+·056	+·011	—·045
Baroda	109	+·030	—·012	—·042
Ahmadābād	156	+·075	+·032	—·043
			Mean	—·044
Intermediate.				
Deesa	465	+·076	+·043	—·033
Stations in or near the Central Indian Highlands.				
Abu	3836	+·041	+·025	—·016
Erinpura	872	+·036	+·019	—·017
Pāli Mārwār	719	+·035	+·016	—·019
			Mean	—·017

Italics show stations observed at in former seasons.

Table IX shows the stations of this season treated similarly, for the sake of comparison ; and includes three former coastal stations to give a mean for this class, which Captain Couchman was unable to give, owing to want of sufficient data. As was expected for coastal stations the change is a large one, *viz.*, —0·058, and when compensation is allowed for the residual is reduced, which tends to confirm the ocean compensation hypothesis.

A pamphlet has been prepared and is now in the press in which various tables and diagrams have been collected for facilitating the computations in connection with the pendulum work.

The health of the party remained good throughout the year. It was inspected by the Superintendent of the Trigonometrical Survey on the 22nd September 1914.

TRIANGULATION.

No. 15 PARTY.

(*Vide* Index Map No. 10.)

BY MAJOR E. A. TANDY, R.E.

PERSONNEL.

Imperial Officers.

Major H. M. Cowie, R.E., in charge up to 26th November 1913.
Major G. A. Beazeley, R.E., in charge from 27th November 1913 to 15th March 1914.
Major E. A. Tandy, R.E., in charge from 16th March to 26th July and from 31st August 1914.
Lieutenant K. Mason, R. E., attached up to 30th April 1914.

Provincial Officers.

Mr. C. H. Tresham, in charge from 27th July to 30th August 1914.
Mr. L. Williams.
„ V. D. B. Collins.
„ V. P. Wainright.
„ G. A. Norman.
„ B. T. Wyatt.
„ C. S. McInnes.
„ Abdul Karim.
„ K. S. Gopalachari, B. A.
„ A. J. Moore.
„ N. S. Harihara Iyer.

Upper Subordinate Service.

Mr. Jugal Behari Lal.

Lower Subordinate Service.

24 Computers, etc.

During the cold weather of 1913-14, the field work was carried out by four detachments as follows :—

(1) Messrs. Tresham and Williams—*The Sambalpur Series* and afterwards *the Buldāna Series.*

(2) Messrs. Norman and Abdul Karim—*The Nāgā Hills Series* and *the Jaintiā Hills Series.*

(3) Messrs. Wyatt and Harihara Iyer—*The Naldrug Series.*

(4) Messrs. Collins and Jugal Behari Lal—*The Bombay City Framework* and afterwards *the Ashta Series.*

NOTE.—Mr. Abdul Karim was transferred from the party on the close of field work, and Mr. Moore joined the party in exchange with Mr. H. Iyer in July.

Particulars of Triangulation Outturn during the year.

	PRINCIPAL.	SECONDARY.				
	Sambalpur.	Naga Hills.	Jaintia Hills.	Buldāna.	Ashta.	Naldrug.
Number of Stations observed at	5	12	6	20	16	32
„ „ newly fixed and built.	0	1	14	20	19	28
Length of triangulation completed in miles.	52	127	45	104	100	265
Length of triangulation remaining to be done.	0	0	57	...	36	0
Area of triangulation in square miles	1444	2200	370	1431	1037	4429
Number of triangles observed	...	9	4	18	14	32
„ Astronomical Azimuths observed.	1	...	...	...	...	...
Maximum triangular error	0″·316	4″·26	...	0″·98	3″·07	4″·94
Average „ „	0″·119	1″·23	...	0″·44	1″·07	2″·16
Mean closing error in latitude	0″·155	1″·59	...	...	...	0″·15
„ „ „ „ longitude	0″·040	0″·02	...	...	...	0″·30
„ „ „ „ height	2·5ft.	11·8ft.	...	...	...	10ft.
„ „ „ „ azimuth	3″·185	10″·56	...	...	...	17″·84
„ „ „ „ log. side, the unit being the seventh place of decimals.	...	280	...	...	...	051
Theodolite used	T. and S. 12-inch. Micr. No. V.	T. and S. 12-inch. Micr. No. III.	T. and S. 12-inch. Micr. No. III.	T. and S. 8-inch. Micr. No. 1311.	T. and S. 8-inch. Micr. Nos. 1315 and 1316.	T. and S. 8-inch. Micr. No. 956.

PRINCIPAL TRIANGULATION.

The Sambalpur Series.—The building of stations having been completed in the previous season, all that remained to be done was to observe the last two figures which make connection with the East Coast Series. This was carried out by Mr. Tresham, while Mr. Williams proceeded direct to lay out the Buldāna Series which had been allotted to this detachment for the remainder of the season.

The work lay in the Ganjām Hill tracts where only coolie transport is available. The detachment marched from Parlakimedi railway station early in November and returned there in the middle of January, the only serious delay being due to a little bad weather at the first station, Deodongar H. S.

One astronomical azimuth, as shown in the table of outturn, was observed at Deodongar H. S. in latitude 18° 55′.

The total length of the Sambalpur Series, which runs along meridian 84° and extends from the Calcutta Longitudinal to the East Coast Series, is 331 miles. The whole of the observations were carried out by Mr. C. H. Tresham, and the following figures, giving a summary of the whole work, and showing the very satisfactory connection with the East Coast Series, do great credit to his skill and care as an observer.

Particulars of Sambalpur Series.

Number of principal stations observed at	37
" " " newly fixed	33
" " secondary stations fixed	6
" " astronomical azimuths observed	4
" " figures	12
Length of Series in miles (23° 16′ to 18° 52′)	331
Area covered by principal figures in square miles	9028
Average triangular error of 51 triangles (3 errors above 1″)	0″·293
Largest triangular error	1″·526
Average number of measures of each angle	56
Apparent error of observation (*e*)	0″·44
" " graduation (*c*)	1″·69
Cost of triangulation per square mile about	Rs. 6/-

Comparison of old and new values in the connection between the Sambalpur and East Coast Series.

		East Coast Series.	Sambalpur Series.	Difference.
		(1857-58)	(1913-14)	
Deodongar H. S.	Latitude	18°54′32″·37	18°54′32″·51	0″·14
	Longitude	84-3-35·84	84-3-35·80	0·04
	Azimuth	72-5-33·76	72-5-36·94	3·18
	Height	4534ft.	4534 ft.	*Nil.*
	Side in feet	99839·4	99838·8	0·6ft.
Himāgiri H. S.	Latitude	18°-49′-27″·29	18°-49′-27″·46	0″·17
	Longitude	83-47-06·69	83-47-06·65	0·04
	Azimuth	352-0-13·90	252-00-17·09	3·19
	Height	3709ft.	3704ft.	5ft.

SECONDARY TRIANGULATION.

The Buldāna Series.—The laying out of this series had been commenced by Mr. Collins in the previous season, when it was described as the *Akola* Series. It has now been renamed as above, and has been carried for a distance of 104 miles between latitude 20° 12′, and 21° 43′ along the meridian 76° 30′. This being all that is required for current topographical purposes, the series is not to be carried any further for the present.

Owing to the flatness of the ground Mr. Williams found considerable difficulty in laying out the series, and the sides of the triangles are small and graze along the ground throughout the greater part of their length. As a result of these difficulties in laying out, Mr. Tresham, who commenced observing on the 1st February after completing the Sambalpur Series, was able to catch up Mr. Williams by the 16th April, when field work was closed.

Nāgā Hills Series and *Jaintiā Hills Series.*—The Nāgā Hills Series was referred to in last year's report as the *Manipur Series.* This connection between the Assam Valley Series and the Manipur Meridional Series had been reconnoitred, laid out, and partly observed during the previous season by Mr. Norman, who therefore had only to complete the observations of the southern half of the series, while Mr. Abdul Karim reconnoitred, westwards from it, a new series to link up as an extension of the old Jaintiā Hills Series. Observations were commenced on the 8th of November, and the Nāgā Hills Series was completed on the 28th January. Mr. Norman then observed westwards along the Khāsia Hills Series which had just been laid out. No serious difficulties occurred until the middle of February, from which time onwards clouds, rain, or smoke haze, continuously impeded the work, so that only two figures were observed in the two months up to the middle of April, when work was given up as hopeless. The same cause prevented Mr. Abdul Karim from making good his connection with the old portion of Jaintiā Hills Series, and one more station may have to be built to complete this connection.

The discrepancies in connection with the Manipur Meridional Series were 8 feet in length of side, 12 feet in height, under 11″ in azimuth, 0″·01 in longitude and nearly 1″·6 in latitude. This considerable discrepancy in latitude is being made a subject for further enquiry.

The Naldrug Series.—This new series was commenced and completed during the season in the face of considerable impediments. It runs due south along the meridian 76° 30′ from the Bombay Longitudinal Series, in latitude 18°, to latitude 15° 30′, where it turns eastwards to connect with the Great Arc Series.

Although the detachment arrived at Sholāpur railway station on October 27th observations were not commenced until the 1st January, first owing to prolonged delays in getting the Hyderābād officials to pass on permission for the commencement of the work, and secondly because the observer Mr. Wyatt had to assist Mr. Harihara Iyer in getting a fair start with the reconnoitring which was at first much delayed through the flatness of the ground; also one of the stations, Daud Malik, of the proposed base was found to have been destroyed, so that another one had to be selected.

After this, work was pushed on rapidly to the completion of the observations on the 17th April, the only impediments being a good deal of haze and wet weather towards the end.

The connection with the Great Arc Series proved satisfactory, giving discrepancies of 2 feet in length of side, 10 feet in height, under 18″ in azimuth, and an average of 0″·22 in the coordinates of the two stations.

Ashta Series.—This connection between the Karāchi Longitudinal Series and the Khandwā Series, along the meridian 76° 30′ was commenced on the 19th February after the completion of the Bombay traverse work. The whole of the reconnaissance and building were completed, and also the observing of the first 100 miles, thus leaving the northern 36 miles to be observed in order to complete the series.

There were some slight delays in commencing, and Mr. Collins had to assist Mr. Jugal Behari Lal in getting a start with the reconnaissance and

building, so that he was not free to return and commence observing until the 12th March. Progress in the southern half of the series was slow owing to the flatness of the country and a good deal of dense jungle. The northern half was favourable for triangulation, but a strike amongst Garhwali khalasis and a riding accident to Mr. Jugal Behari Lal, delayed the completion of the work, which was closed on the 3rd May.

Bombay City framework.—A report on this work, which was completed during the season, is given in Part III.—Special Reports, at the end of this Volume.

TIDAL OPERATIONS.

No. 16 PARTY.

(*Vide* Index Map No. 10.)

BY MR. SYED AULAD HOSSEIN, K. B.

Tidal registrations by means of self-registering tide-gauges were continued during the past year at the following ports:—

Aden, Karāchi, Apollo Bandar (Bombay), Prince's Dock (Bombay), Madras, Kidderpore, Rangoon, Moulmein and Port Blair. The work was carried out under the direction of this department, but the immediate control of all the tidal observatories was entrusted to the local officers of the ports concerned.

PERSONNEL.

Provincial Officers.

Mr. Syed Aulad Hossein, K.B., in charge.
„ Syed Zille Hasnain.

Lower Subordinate Service.

1 Clerk.
15 Computers.
2 Tidal Observatory Clerks.
2 Artificers.

In addition to the automatic tidal registrations at the above ports, readings of high and low water were taken during daylight on tide-poles at Bhaunagar and Akyab under the direction of the respective Port Officers throughout the year. The Port Officer of Chittagong also supplied to this Party tidal diagrams recorded by a small self-registering river-gauge at Chittagong from which the times and heights of high and low water were read in this office. The record of high and low water thus obtained at Bhaunagar, Akyab and Chittagong was used for the purpose of checking the corresponding predictions.

LIST OF TIDAL STATIONS.

The following is a complete list of the ports at which tidal observations have been carried out from the commencement of the tidal operations in 1874 up to the present time. The permanent stations are shown in italics; the others are minor stations which were closed on the completion of the requisite registrations.

Serial No.	Stations.	Automatic or Personal observations.	Date of commencement of observations.	Date of closing of observations.	Number of years of observations.	Remarks.
1	Suez	Automatic	1897	1903	7	
2	Perim	„	1898	1902	5	
3	*Aden*	„	1879	Still working	35	
4	Maskat	„	1893	1898	5	
5	Bushire	„	1892	1901	8	
6	*Karāchi*	„	1868 1881	1880 Still working	*13 34 } 47	* Small tide-gauge working.
7	Hanstal	„	1874	1875	1	Tide-tables not published.
8	Navīnar	Automatic	1874	1875	1	Tide-tables not published.
9	Okha Point	„	1874 Restarted 1904	1875 1906	1 1 } 2	Year 1904-05 is excluded.
10	Porbandar	Personal	1893	1894	2	
10A	Porbandar	Automatic	1898	1902	2	Years 1898, 1899 and 1902 are excluded.
11	Port Albert Victor (Kāthiāwār).	Personal	1881	1882	1	

Serial No.	Stations.	Automatic or Personal observations.	Date of commencement of observations.	Date of closing of observations.	Number of years of observations.	Remarks.
11A	Port Albert Victor (Kāthiāwār).	Automatic .	1900	1903	4	
12	Bhaunagar . .	" .	1889	1894	5	
13	*Bombay (Apollo Bandar).*	" .	1878	Still working	36	
14	*Bombay (Prince's Dock).*	"	1888	"	26	
15	Marmagao (Goa) .	" .	1884	1889	5	
16	Kārwār . .	"	1878	1883	5	
17	Beypore . . .	" .	1878	1884	6	
18	Cochin . . .	" .	1886	1892	6	
19	Tuticorin . .	" .	1888	1893	5	
20	Minicoy . . .	" .	1891	1896	5	
21	Galle . . .	" .	1884	1890	6	
22	Colombo . .	" .	1884	1890	6	
23	Trincomalee . .	" .	1890	1896	6	
24	Pāmban Pass . .	" .	1878	1882	4	
25	Negapatam . .	" .	1881	1888	5	Years 1883 to 1885 are excluded.
26	*Madras* . .	" .	1880 Restarted 1895	1890 Still working	10 19 } 29	
27	Cocanāda . .	" .	1886	1891	5	
28	Vizagapatam . .	" .	1879	1885	6	
29	False Point . .	" .	1881	1885	4	
30	Dubiat (Sāgar Island)	" .	1881	1886	5	
31	Diamond Harbour .	" .	1881	1886	5	
32	*Kidderpore* .	" .	1881	Still working	33	
33	Chittagong . .	" .	1886	1891	5	
34	Akyab . . .	" .	1887	1892	5	
35	Diamond Island .	" .	1895	1899	5	
36	Bassein (Burma) .	" .	1902	1903	2	
37	Elephant Point .	" .	1880 Restarted 1884	1881 1888	5	Year 1880-81 is excluded.
38	*Rangoon* . .	" .	1880	Still working	34	
39	Amherst .	" .	1880	1886	6	
40	*Moulmein* . .	" .	1880 Restarted 1909	1886 Still working	6 5 } 11	
41	Mergui . . .	" .	1889	1894	5	
42	*Port Blair* .	" .	1880	Still working	34	

WORKING OF THE OBSERVATORIES.

The tidal observatories at Apollo Bandar (Bombay), Prince's Dock (Bombay) and Karāchi were inspected by Mr. Syed Aulad Hossein. This being the first occasion on which this officer went out to inspect the tidal observatories he was assisted in his inspection by Mr. Syed Zille Hasnain at Bombay. The remaining six observatories were inspected by Mr. Syed Zille Hasnain.

The inspection of each observatory was carried out rigorously, special attention being paid to the following points :—

(a) Checking the working zero of the tide-gauge and comparison of the same with the true zero.

(b) Testing the stability of the tide-gauge by check levelling between its bed plate and the bench-mark of reference.

(c) Testing the zero of the graduated staff with reference to the zero of the tide-gauge.

(d) Thoroughly cleaning and overhauling all the instruments and putting them in perfect working order.

(e) Final adjustments of the tide-gauge and the working zero after cleaning the whole apparatus.

(f) Examination and cleaning of the observatory well and the inlet holes and securing free communication between the sea and the well.

(g) General examination of the observatory cabin with the object of getting any repairs done, if necessary.

The following remarks regarding each observatory may be of interest :—

Aden.—The tide-gauge at this observatory has generally worked well. The driving clock stopped six times during the year, the longest interruption in the tidal registrations on this account being of 14 hours.

Karāchi.—The tidal registrations at this observatory have, on the whole, been satisfactory. At the time of the inspection it was found that the communication between the sea and the observatory well was partially blocked owing to mud having accumulated on the outside of the well. The mud was thoroughly removed and free communication was restored. The Inspecting Officer noticed that while he was at the observatory private boats frequently struck against the piles of the cabin, causing at times considerable oscillation of the tide-gauge. It was brought to the notice of the Chief Engineer of the Port who was requested to take necessary action in the matter.

Apollo Bandar (*Bombay*).—The tidal registrations at this observatory have as usual been carried out very satisfactorily during the year.

Prince's Dock (*Bombay*).—There have been several interruptions in the registrations of the tide-gauge chiefly on account of the breaking of the pencil wire or the sticking of the pencil in the vertical slide. These interruptions were of more than usual frequency in the first half of the year under report. It is difficult to assign any particular reason for it. The mechanism of this tide-gauge is rather delicate and it requires very careful and gentle handling. Whenever, therefore, there are frequent interruptions in the working of the tide-gauge, the only way to account for them would appear to be that the gauge is not receiving the attention which it requires from the observatory clerk. The well of the tide-gauge was cleaned more than two years ago. Consequently when the observatory was inspected a large quantity of mud was found inside the well. The matter was reported to the Chief Engineer of the Port. The well has since been cleaned.

Madras.—It was mentioned in last year's report that the tidal registrations at the old observatory were stopped in August 1913, owing to the passage between the sea and the tide-gauge well having been completely blocked by sand. It was decided to abandon this observatory and build a new one at the west entrance to the harbour. In the beginning of November 1913 it was found that owing to the change of the monsoon from South-West to North-East the accretion of sand which blocked the inlet to the tide-gauge well had practically disappeared and the communication between the sea and the well was so far cleared as to render the working of the tide-gauge possible. The tidal registrations at the old observatory were accordingly restarted on the 12th November 1913. There was still a good deal of sand outside the observatory and it was feared that the passage between it and the sea may again be blocked at any time. The resumption of the tidal registrations at the old observatory did not, therefore, alter the decision to build the new observatory. The construction of

the latter, however, took a much longer time than was at first expected and it was not ready before 21st February 1914. The tide-gauge was removed from the old to the new observatory the same after-noon and it has been working there very satisfactorily up to the present time.

Kidderpore.—The tide-gauge has worked well during the past year, no interruptions having occurred in the tidal registrations. When the observatory was inspected in December last it was found that the cabin needed thorough repairs and some of the piles on which the cabin rested were showing signs of wear and tear. The Deputy Conservator of the Port was requested to do the needful.

Rangoon.—There have been no breaks in the tidal registrations at this observatory. The driving clock of the Anemometer stopped several times during the year. In December last the Inspecting Officer noticed that at rising tide the water on the graduated staff read nearly 3 inches higher than what the recording pencil showed on the diagram of the tide-gauge and at falling tide the position was reversed, that is, the record of the pencil on the tide-gauge was equally higher than the reading of the graduated staff. This showed that the communication between the river and the tide-gauge well was not quite free. Steps were taken at once to examine the bottom of the well and have it cleared of mud both from inside and outside. After this was done free communication between the river and the well was restored and the readings of the graduated staff and the recording pencil on the tide-gauge agreed very closely.

Moulmein.—There was only one interruption of 34 hours in the registrations of the tide-gauge at this observatory in July last owing to the stoppage of the driving clock. With this exception, the tide-gauge has worked satisfactorily.

Port Blair.—The tide-gauge and the auxiliary instruments at this observatory have worked very satisfactorily during the past year.

COMPUTATIONS AND REDUCTION OF OBSERVATIONS.

All the computations pertaining to past year's work have been completed and there are no arrears. The tidal observations at the nine working stations for the year 1913 have been reduced by harmonic analysis and the values for the tidal constants thus determined are shown in the attached tables.

These tables give the amplitudes (R) and the epochs (ζ) at the various stations; they also give the values of H and κ which are connected with R and ζ in such a way, through the various astronomical quantities involved in the position of the sun and the moon, that if the tidal observations were consistent from year to year H and κ would come out the same from each year's reductions.

ADEN, 1913.

Short Period Tides.

A_0 = 5·860 feet.

S_1	H = R =	·110	M_6	R =	·006	Q_1	R =	·176	T_2	R =	·007
	κ = ζ =	173°·15		ζ =	265°·52		ζ =	122°·25		ζ =	256°·37
S_2	H = R =	·676		H =	·006		H =	·149		H =	·007
	κ = ζ =	245°·49		κ =	7°·20		κ =	25°·25		κ =	257°·41
S_4	H = R =	·007	M_8	R =	·002	L_2	R =	·037	$(MS)_4$	R =	·020
	κ = ζ =	244°·61		ζ =	281°·89		ζ =	190°·85		ζ =	13°·36
S_6	H = R =	·007		H =	·003		H =	·067		H =	·020
	κ = ζ =	193°·24		κ =	177°·47		κ =	241°·83		κ =	167°·26
S_8	H = R =	·002	O_1	R =	·775	N_2	R =	·451	$(2SM)_2$	R =	·019
	κ = ζ =	45°·00		ζ =	74°·79		ζ =	127°·14		ζ =	263°·93
				H =	·655		H =	·468		H =	·020
				κ =	37°·91		κ =	220°·91		κ =	110°·03
M_1	R =	·077	K_1	R =	1·456	λ_2	R =	...	$2N_2$	R =	·076
	ζ =	191°·67		ζ =	204°·24		ζ =	...		ζ =	152°·20
	H =	·034		H =	1·308		H =	...		H =	·078
	κ =	350°·60		κ =	34°·69		κ =	....		κ =	185°·85
M_2	R =	1·497	K_2	R =	·231	ν_2	R =	·134	$(M_2N)_4$	R =	·009
	ζ =	74°·16		ζ =	36°·73		ζ =	239°·89		ζ =	24°·39
	H =	1·554		H =	·176		H =	·139		H =	·009
	κ =	228°·06		κ =	237°·64		κ =	247°·73		κ =	272°·05
M_3	R =	·020	P_1	R =	·403	μ_2	R =	·063	$(M_2K_1)_3$	R =	·027
	ζ =	356°·19		ζ =	222°·91		ζ =	255°·61		ζ =	62°·76
	H =	·021		H =	·403		H =	·068		H =	·026
	κ =	227°·03		κ =	32°·51		κ =	203°·40		κ =	47°·11
M_4	R =	·010	J_1	R =	·070	R_2	R =	...	$(2M_2K_1)_3$	R =	·005
	ζ =	48°·58		ζ =	179°·17		ζ =	...		ζ =	296°·08
	H =	·010		H =	·060		H =	...		H =	·005
	κ =	356°·37		κ =	70°·07		κ =	...		κ =	53°·42

Long Period Tides.

	R	ζ	H	κ
Lunar Monthly Tide	·045	138°·53	·052	198°·66
„ Fortnightly „	·065	335°·76	·045	23°·41
Luni-Solar „ „	·021	102°·23	·022	308°·33
Solar-Annual „ . . .	·401	72°·62	·401	353°·03
„ Semi-Annual „	·178	293°·47	·178	134°·28

KARĀCHI, 1913.

Short Period Tides.

$A_0 = 7{\cdot}243$ feet.

S_1	H = R =	·105	M_6	R =	·047	Q_1	R =	·175	T_2	R =	·029
	κ = ζ =	189°·41		ζ =	95°·47		ζ =	132°·33		ζ =	81°·30
S_2	H = R =	·974		H =	·052		H =	·148		H =	·029
	κ = ζ =	322°·27		κ =	201°·61		κ =	37°·67		κ =	82°·40
S_4	H = R =	·007	M_8	R =	·008	L_2	R =	·063	$(MS)_4$	R =	·034
	κ = ζ =	1°·55		ζ =	318°·65		ζ =	266°·53		ζ =	143°·81
S_6	H = R =	·009		H =	·009		H =	·114		H =	·036
	κ = ζ =	278°·70		κ =	220°·18		κ =	318°·20		κ =	298°·69
S_8	H = R =	·001	O_1	R =	·783	N_2	R =	·626	$(2SM)_2$	R =	·016
	κ = ζ =	116°·57		ζ =	82°·17		ζ =	179°·88		ζ =	251°·00
				H =	·662		H =	·649		H =	·017
				κ =	46°·84		κ =	275°·94		κ =	95°·62
M_1	R =	·07[illegible]	K_1	R =	1·483	λ_2	R =	...	$2N_2$	R =	·076
	ζ =	200°·30		ζ =	214°·83		ζ =	...		ζ =	209°·85
	H =	·033		H =	1·333		H =	...		H =	·079
	κ =	359°·97		κ =	45°·22		κ =	...		κ =	246°·58
M_2	R =	2·506	K_2	R =	·326	ν_2	R =	·208	$(M_2N)_4$	R =	·022
	ζ =	138°·07		ζ =	116°·98		ζ =	286°·37		ζ =	102°·35
	H =	2·601		H =	·247		H =	·215		H =	·023
	κ =	293°·45		κ =	317°·77		κ =	296°·38		κ =	353°·78
M_3	R =	·047	P_1	R =	·402	μ_2	R =	·067	$(M_2K_1)_3$	R =	·052
	ζ =	95°·57		ζ =	232°·80		ζ =	322°·71		ζ =	93°·19
	H =	·049		H =	·402		H =	·072		H =	·048
	κ =	328°·65		κ =	42°·45		κ =	273°·48		κ =	78°·97
M_4	R =	·020	J_1	R =	·068	R_2	R =	...	$(2M_2K_1)_3$	R =	·017
	ζ =	27°·11		ζ =	194°·30		ζ =	...		ζ =	211°·97
	H =	·021		H =	·058		H =	...		H =	·017
	κ =	337°·87		κ =	84°·34		κ =	...		κ =	332°·34

Long Period Tides.

	R	ζ	H	κ
Lunar Monthly Tide . . .	·050	187°·41	·057	246°·73
„ Fortnightly „	·035	354° 19	·024	40°·24
Luni-Solar „ „ . .	·031	76°·78	·032	251°·40
Solar-Annual „ . .	·194	147°·27	·194	67°·62
„ Semi-Annual „ . .	·144	304°·30	·144	145°·00

BOMBAY (APOLLO BANDAR), 1913.

Short Period Tides.

A_0=10·186 feet.

S_1	H = R =	·096	M_6	R =	·014	Q_1	R =	·173	T_2	R =	·058
S_1	κ = ζ =	194°·67	M_6	ζ =	324°·72	Q_1	ζ =	135°·87	T_2	ζ =	65°·13
S_2	H = R =	1·565	M_6	H =	·016	Q_1	H =	·146	T_2	H =	·058
S_2	κ = ζ =	3°·87	M_6	κ =	72°·06	Q_1	κ =	41°·84	T_2	κ =	66°·24
S_4	H = R =	·023	M_8	R =	·005	L_2	R =	·047	$(MS)_4$	R =	·069
S_4	κ = ζ =	234°·20	M_8	ζ =	92°·73	L_2	ζ =	251°·72	$(MS)_4$	ζ =	221°·81
S_6	H = R =	·004	M_8	H =	·006	L_2	H =	·084	$(MS)_4$	H =	·072
S_6	κ = ζ =	145°·01	M_8	κ =	355°·85	L_2	κ =	303°·59	$(MS)_4$	κ =	17°·59
S_8	H = R =	·001	O_1	R =	·763	N_2	R =	·942	$(2SM)_2$	R =	·035
S_8	κ = ζ =	167°·01	O_1	ζ =	84°·09	N_2	ζ =	217°·32	$(2SM)_2$	ζ =	263°·51
			O_1	H =	·646	N_2	H =	·978	$(2SM)_2$	H =	·036
			O_1	κ =	49°·17	N_2	κ =	313°·99	$(2SM)_2$	κ =	107°·73
M_1	R =	·076	K_1	R =	1·545	λ_2	R =	...	$2N_2$	R =	·160
M_1	ζ =	203°·64	K_1	ζ =	214°·59	λ_2	ζ =	...	$2N_2$	ζ =	244°·81
M_1	H =	·033	K_1	H =	1·388	λ_2	H =	...	$2N_2$	H =	·166
M_1	κ =	3°·50	K_1	κ =	44°·97	λ_2	κ =	...	$2N_2$	κ =	282°·36
M_2	R =	3·816	K_2	R =	·506	ν_2	R =	·307	$(M_2N)_4$	R =	·010
M_2	ζ =	175°·51	K_2	ζ =	154°·55	ν_2	ζ =	321°·36	$(M_2N)_4$	ζ =	318°·99
M_2	H =	3·962	K_2	H =	·385	ν_2	H =	·319	$(M_2N)_4$	H =	·010
M_2	κ =	331°·29	K_2	κ =	355°·31	ν_2	κ =	331°·96	$(M_2N)_4$	κ =	211°·44
M_3	R =	·065	P_1	R =	·408	μ_2	R =	·200	$(M_2K_1)_3$	R =	·079
M_3	ζ =	161°·59	P_1	ζ =	234°·45	μ_2	ζ =	2°·61	$(M_2K_1)_3$	ζ =	189°·67
M_3	H =	·068	P_1	H =	·408	μ_2	H =	·216	$(M_2K_1)_3$	H =	·074
M_3	κ =	35°·26	P_1	κ =	44°·12	μ_2	κ =	314°·17	$(M_2K_1)_3$	κ =	175°·82
M_4	R =	·087	J_1	R =	·083	R_2	R =	...	$(2M_2K_1)_3$	R =	·044
M_4	ζ =	358°·62	J_1	ζ =	197°·00	R_2	ζ =	...	$(2M_2K_1)_3$	ζ =	293°·09
M_4	H =	·094	J_1	H =	·072	R_2	H =	...	$(2M_2K_1)_3$	H =	·043
M_4	κ =	310°·18	J_1	κ =	86°·81	R_2	κ =	...	$(2M_2K_1)_3$	κ =	54°·28

Long Period Tides.

	R	ζ	H	κ
Lunar Monthly Tide	·039	174°·37	·045	233°·49
„ Fortnightly „	·067	316°·08	·046	1°·69
Luni-Solar „ „	·018	28°·07	·019	232°·29
Solar-Annual „	·147	112°·49	·147	32°·82
„ Semi-Annual „	·154	330°·88	·154	171°·54

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BOMBAY (PRINCE'S DOCK), 1913.

Short Period Tides.

A_0 = 8·221 feet.

S_1	$H = R =$	·105	M_6	$R =$	·011	Q_1	$R =$	·175	T_2	$R =$	·066
	$\kappa = \zeta =$	192°·64		$\zeta =$	33°·22		$\zeta =$	136°·18		$\zeta =$	53°·94
S_2	$H = R =$	1·597		$H =$	·012		$H =$	·148		$H =$	·066
	$\kappa = \zeta =$	4°·66		$\kappa =$	140°·56		$\kappa =$	42°·15		$\kappa =$	55°·06
S_4	$H = R =$	·026	M_8	$R =$	·004	L_2	$R =$	·061	$(MS)_4$	$R =$	·098
	$\kappa = \zeta =$	222°·14		$\zeta =$	233°·13		$\zeta =$	278°·18		$\zeta =$	245°·13
S_6	$H = R =$	·004		$H =$	·004		$H =$	·110		$H =$	·102
	$\kappa = \zeta =$	191°·89		$\kappa =$	136°·26		$\kappa =$	330°·05		$\kappa =$	40°·91
S_8	$H = R =$	·003	O_1	$R =$	·770	N_2	$R =$	·979	$(2SM)_2$	$R =$	·042
	$\kappa = \zeta =$	165°·96		$\zeta =$	83°·50		$\zeta =$	217°·61		$\zeta =$	263°·06
				$H =$	·651		$H =$	1·017		$H =$	·044
				$\kappa =$	48°·59		$\kappa =$	314°·28		$\kappa =$	107°·28
M_1	$R =$	·076	K_1	$R =$	1·562	λ_2	$R =$	...	$2N_2$	$R =$	·166
	$\zeta =$	205°·11		$\zeta =$	214°·44		$\zeta =$	...		$\zeta =$	246°·14
	$H =$	·033		$H =$	1·403		$H =$	...		$H =$	·172
	$\kappa =$	4°·98		$\kappa =$	44°·81		$\kappa =$	...		$\kappa =$	283°·70
M_2	$R =$	3·920	K_2	$R =$	·502	ν_2	$R =$	·268	$(M_2N)_4$	$R =$	·005
	$\zeta =$	175°·52		$\zeta =$	155°·90		$\zeta =$	323°·08		$\zeta =$	159°·72
	$H =$	4·070		$H =$	·381		$H =$	·278		$H =$	·006
	$\kappa =$	331°·30		$\kappa =$	356°·65		$\kappa =$	333°·69		$\kappa =$	52°·17
M_3	$R =$	·074	P_1	$R =$	·403	μ_2	$R =$	·207	$(M_2K_1)_3$	$R =$	·091
	$\zeta =$	158°·54		$\zeta =$	232°·68		$\zeta =$	5°·83		$\zeta =$	182°·46
	$H =$	·078		$H =$	·403		$H =$	·223		$H =$	·085
	$\kappa =$	32°·21		$\kappa =$	42°·35		$\kappa =$	317°·39		$\kappa =$	168°·62
M_4	$R =$	·098	J_1	$R =$	·082	R_2	$R =$	...	$(2M_2K_1)_3$	$R =$	·053
	$\zeta =$	23°·57		$\zeta =$	198°·32		$\zeta =$	...		$\zeta =$	308°·71
	$H =$	·105		$H =$	·070		$H =$	...		$H =$	·051
	$\kappa =$	335°·13		$\kappa =$	88°·13		$\kappa =$	...		$\kappa =$	69°·90

Long Period Tides.

	R	ζ	H	κ
Lunar Monthly Tide . . .	·031	163°·78	·036	222°·89
„ Fortnightly „	·083	314°·78	·057	0°·39
Luni-Solar „ „	·009	83°·25	·009	287°·47
Solar-Annual „	·150	103°·95	·150	24°·28
„ Semi-Annual „	·153	329°·34	·153	170°·00

MADRAS, 1912-13.

Short Period Tides.

$A_0 = 2{\cdot}362$ feet.

S_1	$H = R =$	·026	M_6	$R =$	·004	Q_1	$R =$	·011	T_2	$R =$	·028
	$\kappa = \zeta =$	60°·80		$\zeta =$	141°·34		$\zeta =$	122°·06		$\zeta =$	106°·03
S_2	$H = R =$	·467		$H =$	·005		$H =$	·009		$H =$	·028
	$\kappa = \zeta =$	270°·56		$\kappa =$	145°·48		$\kappa =$	97°·67		$\kappa =$	265°·85
S_4	$H = R =$	·0001	M_8	$R =$	·001	L_2	$R =$	·040	$(MS)_4$	$R =$	·005
	$\kappa = \zeta =$	111°·80		$\zeta =$	5°·71		$\zeta =$	186°·31		$\zeta =$	99°·09
S_6	$H = R =$	·001		$H =$	·001		$H =$	·048		$H =$	·006
	$\kappa = \zeta =$	326°·31		$\kappa =$	131°·23		$\kappa =$	265°·93		$\kappa =$	220°·47
S_8	$H = R =$	·001	O_1	$R =$	·110	N_2	$R =$	·233	$(2SM)_2$	$R =$	·019
	$\kappa = \zeta =$	271°·76		$\zeta =$	233°·97		$\zeta =$	223°·38		$\zeta =$	338°·48
				$H =$	·093		$H =$	·241		$H =$	·020
				$\kappa =$	324°·96		$\kappa =$	229°·38		$\kappa =$	217°·10
M_1	$R =$	·022	K_1	$R =$	·329	λ_2	$R =$	...	$2N_2$	$R =$	·028
	$\zeta =$	357°·92		$\zeta =$	305°·75		$\zeta =$	...		$\zeta =$	330°·77
	$H =$	·011		$H =$	·296		$H =$	...		$H =$	·029
	$\kappa =$	309°·23		$\kappa =$	336°·90		$\kappa =$	...		$\kappa =$	221°·39
M_2	$R =$	1·044	K_2	$R =$	·154	ν_2	$R =$	·049	$(M_2N)_4$	$R =$	·005
	$\zeta =$	119°·54		$\zeta =$	22°·91		$\zeta =$	275°·46		$\zeta =$	54°·61
	$H =$	1·083		$H =$	·117		$H =$	·051		$H =$	·005
	$\kappa =$	240°·92		$\kappa =$	265°·15		$\kappa =$	273°·85		$\kappa =$	181°·99
M_3	$R =$	·004	P_1	$R =$	090	μ_2	$R =$	·017	$(M_2K_1)_3$	$R =$	·013
	$\zeta =$	22°·75		$\zeta =$	11°·89		$\zeta =$	298°·96		$\zeta =$	186°·49
	$H =$	·004		$H =$	·090		$H =$	·019		$H =$	·012
	$\kappa =$	24°·82		$\kappa =$	340°·27		$\kappa =$	181°·72		$\kappa =$	339°·02
M_4	$R =$	·006	J_1	$R =$	·015	R_2	$R =$	...	$(2M_2K_1)_3$	$R =$	·002
	$\zeta =$	304°·51		$\zeta =$	173°·49		$\zeta =$	...		$\zeta =$	92°·49
	$H =$	·007		$H =$	·013		$H =$	...		$H =$	·002
	$\kappa =$	187°·27		$\kappa =$	319°·26		$\kappa =$	...		$\kappa =$	304°·10

Long Period Tides.

	R	ζ	H	κ
Lunar Monthly Tide . . .	·031	81°·33	·036	196°·71
„ Fortnightly „ . . .	·069	229°·33	·048	348°·73
Luni-Solar „ „ . . .	·021	310°·74	·022	189°·36
Solar-Annual „ . . .	·407	84°·27	·407	205°·89
„ Semi-Annual „ . . .	·347	238°·91	·347	122°·15

KIDDERPORE, 1913.

Short Period Tides.

A_0 = 10·495 feet.

S_1	$H = R$ =	·086	M_6	R =	·139	Q_1	R =	·017	T_2	R =	·167
	$\kappa = \zeta$ =	215°·46		ζ =	201°·71		ζ =	88°·00		ζ =	190°·50
S_2	$H = R$ =	1·592		H =	·156		H =	·015		H =	·167
	$\kappa = \zeta$ =	95°·64		κ =	312°·19		κ =	355°·63		κ =	191°·66
S_4	$H = R$ =	·098	M_8	R =	·065	L_2	R =	·228	$(MS)_4$	R =	·694
	$\kappa = \zeta$ =	102°·00		ζ =	356°·69		ζ =	20°·52		ζ =	270°·17
S_6	$H = R$ =	·0004		H =	·075		H =	·409		H =	·721
	$\kappa = \zeta$ =	56°·31		κ =	264°·00		κ =	72°·88		κ =	67°·00
S_8	$H = R$ =	·001	O_1	R =	·243	N_2	R =	·707	$(2SM)_2$	R =	·112
	$\kappa = \zeta$ =	200°·56		ζ =	57°·18		ζ =	299°·14		ζ =	148°·93
				H =	·205		H =	·734		H =	·116
				κ =	23°·35		κ =	37°·42		κ =	352°·10
M_1	R =	·072	K_1	R =	·451	λ_2	R =	...	$2N_2$	R =	·097
	ζ =	208°·81		ζ =	220°·36		ζ =	...		ζ =	70°·92
	H =	·031		H =	·405		H =	...		H =	·101
	κ =	9°·19		κ =	50°·69		κ =	...		κ =	110°·65
M_2	R =	3·697	K_2	R =	·539	ν_2	R =	·295	$(M_2N)_4$	R =	·283
	ζ =	257°·27		ζ =	249°·34		ζ =	25°·03		ζ =	117°·25
	H =	3·838		H =	·410		H =	·306		H =	·305
	κ =	54°·10		κ =	90°·01		κ =	37°·16		κ =	12°·35
M_3	R =	·062	P_1	R =	·144	μ_2	R =	·313	$(M_2K_1)_3$	R =	·094
	ζ =	64°·11		ζ =	233°·95		ζ =	228°·50		ζ =	30°·26
	H =	·066		H =	·144		H =	·337		H =	·088
	κ =	299°·36		κ =	43°·66		κ =	182°·16		κ =	17°·42
M_4	R =	·702	J_1	R =	·016	R_2	R =	...	$(2M_2K_1)_3$	R =	·041
	ζ =	75°·64		ζ =	279°·82		ζ =	...		ζ =	188°·29
	H =	·756		H =	·014		H =	...		H =	·040
	κ =	29°·29		κ =	169°·02		κ =	...		κ =	311°·62

Long Period Tides.

	R	ζ	H	κ
Lunar Monthly Tide	·207	318°·52	·238	17°·07
„ Fortnightly „	·348	354°·35	·240	38°·83
Luni-Solar „ „	·921	198°·04	·956	41°·22
Solar-Annual „	2·547	222°·50	2·547	142°·78
„ Semi-Annual „	·730	106°·28	·730	306°·85

Rangoon, 1913.

Short Period Tides.

A_0=10·192 feet.

S_1	H = R =	·135	M_6	R =	·224	Q_1	R =	·027	T_2	R =	·055
	κ = ζ =	129°·48		ζ =	337°·77		ζ =	110°·04		ζ =	186°·31
S_2	H = R =	2·247		H =	·250		H =	·023		H =	·055
	κ = ζ =	169°·31		κ =	89°·85		κ =	18°·50		κ =	187°·49
S_4	H = R =	·087	M_8	R =	·084	L_2	R =	·442	$(MS)_4$	R =	·441
	κ = ζ =	268°·10		ζ =	199°·50		ζ =	118°·40		ζ =	49°·74
S_6	H = R =	·012		H =	·098		H =	·793		H =	·458
	κ = ζ =	46°·30		κ =	108°·94		κ =	171°·00		κ =	207°·10
S_8	H = R =	·005	O_1	R =	·359	N_2	R =	1·099	$(2SM)_2$	R =	·176
	κ = ζ =	93°·50		ζ =	50°·59		ζ =	15°·05		ζ =	205°·61
				H =	·304		H =	1·141		H =	·182
				κ =	17°·32		κ =	114°·14		κ =	48°·25
M_1	R =	·023	K_1	R =	·776	λ_2	R =	...	$2N_2$	R =	·155
	ζ =	238°·16		ζ =	204°·41		ζ =	...		ζ =	203°·36
	H =	·010		H =	·697		H =	...		H =	·161
	κ =	38°·81		κ =	34°·72		κ =	...		κ =	244°·18
M_2	R =	5·822	K_2	R =	·785	ν_2	R =	·445	$(M_2N)_4$	R =	·188
	ζ =	333°·81		ζ =	326°·75		ζ =	113°·87		ζ =	249°·96
	H =	6·045		H =	·596		H =	·462		H =	·203
	κ =	131°·17		κ =	167°·38		κ =	126°·79		κ =	146°·41
M_3	R =	·052	P_1	R =	·183	μ_2	R =	·515	$(M_2K_1)_3$	R =	·130
	ζ =	105°·28		ζ =	253°·90		ζ =	330°·98		ζ =	63°·78
	H =	·055		H =	·183		H =	·555		H =	·121
	κ =	341°·32		κ =	63°·64		κ =	285°·70		κ =	51°·45
M_4	R =	·499	J_1	R =	·037	R_2	R =	...	$(2M_2K_1)_3$	R =	·122
	ζ =	211°·25		ζ =	228°·93		ζ =	...		ζ =	279°·38
	H =	·538		H =	·032		H =	...		H =	·118
	κ =	165°·97		κ =	117°·83		κ =	...		κ =	43°·79

Long Period Tides.

	R	ζ	H	κ
Lunar Monthly Tide	·193	328°·85	·222	27°·12
„ Fortnightly „	·252	342°·09	·174	26°·00
Luni-Solar „ „	·450	197°·29	·467	39°·98
Solar-Annual „	1·124	228°·61	1·124	148°·88
„ Semi-Annual „	·162	127°·67	·162	328°·21

MOULMEIN, 1913.

Short Period Tides.

A_0 = 8·410 feet.

S_1	H=R =	·094	M_6	R =	·067	Q_1	R =	·037	T_2	R =	·064
	κ=ζ =	136°·43		ζ =	68°·45		ζ =	150°·55		ζ =	144°·70
S_2	H=R =	1·557		H =	·075		H =	·031		H =	·064
	κ=ζ =	143°·78		κ =	180°·82		κ =	59°·16		κ =	145°·88
S_4	H=R =	·087	M_8	R =	·039	L_2	R =	·363	$(MS)_4$	R =	·766
	κ=ζ =	222°·52		ζ =	197°·71		ζ =	104°·83		ζ =	41°·90
S_6	H=R =	·003		H =	·046		H =	·651		H =	·796
	κ=ζ =	219°·56		κ =	107°·54		κ =	157°·48		κ =	199°·36
			O_1	R =	·275	N_2	R =	·749	$(2SM)_2$	R =	·147
S_8	H=R =	·003		ζ =	73°·29		ζ =	348°·88		ζ =	187°·49
	κ=ζ =	348°·69		H =	·232		H =	·778		H =	·152
				κ =	40°·12		κ =	88°·13		κ =	30°·03
M_1	R =	·020	K_1	R =	·512	λ_2	R =	...	$2N_2$	R =	·091
	ζ =	239°·34		ζ =	206°·27		ζ =	...		ζ =	153°·69
	H =	·009		H =	·460		H =	...		H =	·095
	κ =	40°·04		κ =	36°·58		κ =	...		κ =	194°·72
M_2	R =	3·982	K_2	R =	·497	ν_2	R =	·305	$(M_2N)_4$	R =	·335
	ζ =	311°·74		ζ =	302°·55		ζ =	98°·76		ζ =	241°·86
	H =	4·134		H =	·378		H =	·3[illegible]7		H =	·361
	κ =	109°·20		κ =	143°·17		κ =	111°·82		κ =	138°·57
M_3	R =	·059	P_1	R =	·145	μ_2	R =	·409	$(M_2K_1)_3$	R =	·147
	ζ =	97°·36		ζ =	255°·04		ζ =	312°·05		ζ =	88°·32
	H =	·063		H =	·145		H =	·440		H =	·137
	κ =	333°·55		κ =	64°·78		κ =	266°·97		κ =	76°·08
M_4	R =	·885	J_1	R =	·016	R_2	R =	...	$(2M_2K_1)_3$	R =	·121
	ζ =	205°·66		ζ =	227°·88		ζ =	...		ζ =	287°·54
	H =	·954		H =	·013		H =	...		H =	·117
	κ =	160°·58		κ =	116°·72		κ =	...		κ =	52°·15

Long Period Tides.

	R	ζ	H	κ
Lunar Monthly Tide . . .	·427	311°·63	·490	9°·84
„ Fortnightly „	·491	347°·31	·338	31°·11
Luni-Solar „ „ . . .	1·151	200°·23	1·195	42°·77
Solar-Annual „ . . .	2·269	230°·16	2·269	150°·42
„ Semi-Annual „ . . .	·725	97°·12	·725	297°·65

Port Blair, 1913.

Short Period Tides.

$A_0 = 4{\cdot}828$ feet.

S_1	H = R =	·022	M_6	R =	·005	Q_1	R =	·014	T_2	R =	·027
	κ = ζ =	105°·84		ζ =	293°·84		ζ =	311°·80		ζ =	354°·35
S_2	H = R =	·976		H =	·006		H =	·012		H =	·027
	κ = ζ =	314°·12		κ =	45°·22		κ =	219°·90		κ =	355°·53
S_4	H = R =	·004	M_8	R =	·001	L_2	R =	·091	$(MS)_4$	R =	·017
	κ = ζ =	160°·02		ζ =	138°·81		ζ =	233°·02		ζ =	22°·19
S_6	H = R =	·001		H =	·002		H =	·164		H =	·018
	κ = ζ =	45°·00		κ =	47°·33		κ =	285°·51		κ =	179°·32
S_8	H = R =	·001	O_1	R =	·179	N_2	R =	·401	$(2SM)_2$	R =	·019
	κ = ζ =	200°·56		ζ =	333°·32		ζ =	172°·91		ζ =	306°·09
				H =	·152		H =	·416		H =	·020
				κ =	299°·81		κ =	271°·64		κ =	148°·97
M_1	R =	·030	K_1	R =	·451	λ_2	R =	...	$2N_2$	R =	·061
	ζ =	135°·14		ζ =	136°·31		ζ =	...		ζ =	231°·37
	H =	·013		H =	·406		H =	...		H =	·063
	κ =	295°·67		κ =	326°·63		κ =	...		κ =	271°·72
M_2	R =	1·941	K_2	R =	·332	ν_2	R =	·126	$(M_2N)_4$	R =	·005
	ζ =	122°·58		ζ =	108°·84		ζ =	271°·52		ζ =	167°·91
	H =	2·016		H =	·252		H =	·130		H =	·005
	κ =	279°·71		κ =	309°·48		κ =	284°·10		κ =	63°·77
M_3	R =	·002	P_1	R =	·131	μ_2	R =	·09	$(M_2K_1)_3$	R =	·014
	ζ =	139°·76		ζ =	155°·07		ζ =	352°·51		ζ =	122°·99
	H =	·002		H =	·131		H =	·101		H =	·013
	κ =	15°·46		κ =	324°·79		κ =	306°·76		κ =	110°·44
M_4	R =	·013	J_1	R =	·029	R_2	R =	...	$(2M_2K_1)_3$	R =	·007
	ζ =	157°·59		ζ =	99°·11		ζ =	...		ζ =	101°·47
	H =	·014		H =	·025		H =	...		H =	·007
	κ =	111°·85		κ =	348°·14		κ =	...		κ =	225°·41

Long Period Tides.

	R	ζ	H	κ
Lunar Monthly Tide . . .	·013	271°·86	·015	330°·25
„ Fortnightly „	·068	325°·24	·047	9°·40
Luni-Solar „ „ . .	·005	64°·81	·005	267°·69
Solar-Annual „ . . .	·168	232°·24	·168	152°·51
„ Semi-Annual „	·080	303°·64	·080	144°·19

DATA FORWARDED TO ENGLAND.

The following data were prepared and supplied to the Director, National Physical Laboratory, Teddington, England, during the year under report:—

(*a*) Values of the tidal constants for 40 ports for the tide-tables for 1917, ready for use for the tide-predicting machine.

(*b*) Actual values of high and low water during 1912 at 12 stations. These include nine stations at which regular tidal observations by self-registering tide-gauges were carried out, two stations at which high and low water readings were taken during daylight on tide-poles, and one station at which times and heights of high and low water were obtained from the diagrams of a small river-gauge supplied by the Port Officer.

(*c*) Comparisons of the above with predicted values for 1912, the errors being tabulated in such form as to be of use in improving the predictions.

ERRORS IN PREDICTIONS.

The percentage and the amount of errors in the predicted times and heights of high and low water for the year 1913, as given in the tide-tables, have been determined by comparison with the actual values obtained from tidal registrations at the 9 stations now working. Similar information has also been compiled for 3 stations at which regular tidal registrations have been stopped, but the actual values of high and low water were obtained from tide-pole readings in the case of two stations (Bhaunagar and Akyab) and from tidal registrations of a small river-gauge in the case of the third station (Chittagong).

The errors are tabulated in the five tables herewith appended.

No. 1.

Statement showing the percentage and the amount of the errors in the predicted times of high water at the various tidal stations for the year 1913.

STATIONS.	Automatic or tide-pole observations.	Number of comparisons between actual and predicted values.	Errors of 5 minutes and under.	Errors over 5 minutes and under 15 minutes.	Errors over 15 minutes and under 20 minutes.	Errors over 20 minutes and under 30 minutes.	Errors over 30 minutes.
			Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
Aden	Auto.	664	40	47	7	4	2
Karāchi . . .	„	701	40	39	12	6	3
Bhaunagar . . .	T. P.	365	66	34	0	0	0
Bombay (Apollo Bandar) .	Auto.	705	37	46	7	7	3
Bombay (Prince's Dock) .	„	672	51	40	5	2	2
Madras	„	406	20	55	12	11	2
Kidderpore . . .	„	705	33	43	11	8	5
*Chittagong . . .	„	696	19	30	14	16	21
Akyab	T. P.	365	98	1	0	1	0
Rangoon . . .	Auto.	705	53	33	8	5	1
Moulmein . . .	„	702	26	38	15	16	5
Port Blair . . .	„	705	29	51	10	7	3

* Observations taken with a small river-gauge by the Port Officer.

No. 2.

Statement showing the percentage and the amount of the errors in the predicted times of low water at the various tidal stations for the year 1913.

Stations.	Automatic or tide-pole observations.	Number of comparisons between actual and predicted values.	Errors of 5 minutes and under.	Errors over 5 minutes and under 15 minutes.	Errors over 15 minutes and under 20 minutes.	Errors over 20 minutes and under 30 minutes.	Errors over 30 minutes.
			Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
Aden	Auto.	661	42	40	10	5	3
Karāchi . . .	,,	705	36	37	10	12	5
Bhaunagar . . .	T. P.	365	69	31	0	0	0
Bombay (Apollo Bandar) .	Auto.	705	41	43	8	5	3
Bombay (Prince's Dock) .	,,	637	48	40	5	4	3
Madras	,,	405	33	47	13	6	1
Kidderpore . . .	,,	704	24	37	13	17	9
*Chittagong . . .	,,	699	21	25	14	17	23
Akyab	T. P.	365	98	2	0	0	0
Rangoon . . .	Auto.	705	32	36	14	14	4
Moulmein . . .	,,	702	20	23	13	21	23
Port Blair . . .	,,	705	34	48	9	6	3

* Observations taken with a small river-gauge by the Port Officer.

No. 3.

Statement showing the percentage and the amount of the errors in the predicted heights of high water at the various tidal stations for the year 1913.

Stations.	Automatic or tide-pole observations.	Number of comparisons between actual and predicted values.	Mean range at springs in feet.	Errors of 4 inches and under.	Errors over 4 inches and under 8 inches.	Errors over 8 inches and under 12 inches.	Errors over 12 inches.
				Per cent.	Per cent.	Per cent.	Per cent.
Aden	Auto.	664	6·7	92	8	0	0
Karāchi . . .	,,	704	9·3	65	31	4	0
Bhaunagar . . .	T. P.	365	31·4	57	37	6	0
Bombay { Apollo Bandar .	Auto.	705	13·9	64	28	6	2
Bombay { Prince's Dock .	,,	672	13·9	62	29	8	1
Madras . . .	,,	406	3·5	87	13	0	0
Kidderpore . . .	,,	705	11·7	40	21	18	21
*Chittagong . . .	,,	696	13·3	45	30	17	8
Akyab	T. P.	365	8·3	89	9	2	0
Rangoon . . .	Auto.	705	16·4	53	32	11	4
Moulmein . . .	,,	702	12·7	33	27	21	19
Port Blair . . .	,,	705	6·6	92	8	0	0

* Observations taken with a small river-gauge by the Port Officer.

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No. 4.

Statement showing the percentage and the amount of the errors in the predicted heights of low water at the various tidal stations for the year 1913.

Stations.	Automatic or tide-pole observations.	Number of comparisons between actual and predicted values.	Mean range at springs in feet.	Errors of 4 inches and under.	Errors over 4 inches and under 8 inches.	Errors over 8 inches and under 12 inches.	Errors over 12 inches.
				Per cent.	Per cent.	Per cent.	Per cent.
Aden	Auto.	661	6·7	94	5	1	0
Karāchi	„	705	9·3	80	18	2	0
Bhaunagar	T. P.	365	31·4	57	31	12	0
Bombay { Apollo Bandar	Auto.	705	13·9	65	28	7	0
Bombay { Prince's Dock	„	637	13·9	60	31	8	1
Madras	„	405	3·5	94	6	0	0
Kidderpore	„	704	11·7	41	27	14	18
* Chittagong	„	699	13·3	32	26	19	23
Akyab	T. P.	365	8·3	87	11	1	1
Rangoon	Auto.	705	16·4	24	23	20	33
Moulmein	„	702	12·7	35	23	19	23
Port Blair	„	705	6·6	96	4	0	0

* Observations taken with a small river-gauge by the Port Officer.

No. 5.

Table of average errors in the predicted times and heights of high and low water at the several tidal stations for the year 1913.

Stations.	Automatic or tide-pole observations.	Mean range at springs in feet.	Average Errors: Of time in minutes.		Of height in terms of the range.		Of height in inches.	
			H. W.	L. W.	H. W.	L. W.	H. W.	L. W.
Open Coast.								
Aden	Auto.	6·7	9	9	·000	·000	0	0
Karāchi	„	9·3	10	11	·036	·027	4	3
Bhaunagar	T. P.	31·4	2	2	·003	·005	1	2
Bombay { Apollo Bandar	„	13·9	10	9	·024	·024	4	4
Bombay { Prince's Dock	„	13·9	7	8	·024	·024	4	4
Madras	Auto.	3·5	12	10	·071	·048	3	2
Akyab	T. P.	8·3	0	0	·020	·020	2	2
Port Blair	Auto.	6·6	10	10	·025	·025	2	2
General Mean	...	...	8	7	·025	·022	3	2
Riverain.								
Kidderpore	Auto.	11·7	11	15	·057	·050	8	7
*Chittagong	„	13·3	21	22	·038	·056	6	9
Rangoon	„	16·4	8	12	·025	·051	5	10
Moulmein	„	12·7	13	21	·052	·052	8	8
General Mean	...	...	13	18	·043	·052	7	9

*Observations taken with a small river-gauge by the Port Officer.

The foregoing statements for the year 1913 may be thus summarised :—

Percentage of time predictions within 15 minutes of actuals.

			High water.	Low water.
			Per cent.	Per cent.
Open coast stations.	6	at which predictions were tested by S. R. tide-gauge .	83	82
	2	" " " tide-pole . .	100	100
Riverain stations.	4	" " " S. R. tide-gauge .	68	55

Percentage of height predictions within 8 inches of actuals.

			High water.	Low water.
			Per cent.	Per cent.
Open coast stations	6	at which predictions were tested by S. R. tide-gauge .	97	97
	2	" " " tide-pole . .	96	93
Riverain stations.	4	" " " S. R. tide-gauge .	70	58

Percentage of height predictions within one-tenth of mean range at springs.

			High water.	Low water.
			Per cent.	Per cent.
Open coast stations.	6	at which predictions were tested by S. R. tide-gauge .	98	99
	2	" " " tide-pole . .	100	100
Riverain stations.	4	" " " S. R. tide-gauge	94	88

COMPARISON OF THE PREDICTIONS FOR 1913 WITH THOSE FOR THE PREVIOUS YEAR.

The predictions for times and heights of high and low water for 1913 at the nine stations at which tidal observations by self-registering tide-gauges are now being carried out have been found to be practically of the same standard of accuracy as the corresponding predictions for 1912. The only exceptions are Karāchi and Madras: the predictions for times have become better at the former station and worse at the latter since the preceding year.

The greatest difference between the actual and predicted heights of low water for 1913 at the riverain ports was as follows:—

Kidderpore	.	2′ 8″	on 30th July 1913, actuals being lower.
Rangoon .	.	3′ 1″	on 20th September 1913, actuals being lower.
Moulmein	.	2′ 6″	on 8th June 1913, actuals being lower.

TIDE-TABLES.

The tide-tables for the year 1915 have been received from England and distributed to the various officers concerned. The tide-tables for the year 1916 are being published in England and the data for the preparation of the tide-tables for 1917 were despatched to England in May 1914.

The amount realized on the sale of the tide-tables during the year ending September 1914 is Rs. 2,382-7-1.

PROGRAMME FOR SEASON 1914-15.

Tidal observations during the coming year will be continued at the nine observatories now working.

LEVELLING.

No. 17 PARTY.

(*Vide* Index Map No. 10.)

BY MR. H. G. SHAW.

During the year under report, three detachments were employed on levelling operations, as follows:—

PERSONNEL.

Provincial Officers.

Mr. H. G. Shaw, in charge.
„ D. H. Luxa.
„ J. McCraken, from 20th October 1913.
„ T. F. Kitchen.
„ M. S. Ganesa Aiyar, from 5th November 1913.
„ O. D. Jackson.
„ Jiya Lal.
„ Narendra Nath Chuckerbutty.

Upper Subordinate Service.

Mr. Karuna Kumar Das.

Lower Subordinate Service.

1 Computer.
9 Recorders.
2 Clerks.

No. 1 Detachment.

This detachment was employed in the Punjab and Baluchistān on the following lines of levels:—

(1) The extension of the line Ambāla-Solon to Simla, by road, with branch lines to "Prospect Hill" and "Jakko."

(2) Revision of levelling from Jagādhri *viâ* Ambāla to Ludhiāna by road.

(3) Revision of levelling between Ferozepore and Lahore by road.

(4) Levelling from Jacobābād to Quetta along the railway line as far as Sibi and thence along the main road to Quetta.

The line Solon to Simla.—This line was undertaken principally at the request of the Simla Municipality, in order to supply a sufficient number of heights for the large scale Survey of Simla. It was run along the Tonga road as far as Simla, and thence along the "Mall" to the Punjab Secretariat building. Two short branch lines were also run, one to "Prospect Hill" and the other to "Jakko."

This line is of great importance for geodetic purposes as it is one of the several lines running from the plains to the Himālayas, the object of which is to detect in the future any relative changes in the growth of these mountains.

Revision of levelling from Jagādhri viâ *Ambāla to Ludhiāna.*—As mentioned in last year's report, it was found that there were large differences between the old and new values of certain bench-marks on the revision of levelling between Ambāla and Meerut, and it was difficult to assign any definite reason for the same. It was inferred at the time that either the bench-mark "901·6 ^" inscribed on the upper stone step just outside the wooden sill of the western doorway of the tower of St. Paul's Church at Ambāla had settled since 1861—62, or a gross error had occurred in the levelling between Ambāla and Jagādhri. It was with the object of trying to elucidate the above matter, and to account for the discrepancies, if possible, that the levelling between Jagādhri and Ambāla was again revised, and the revision extended from Ambāla to Ludhiāna.

The difference of height between Jagādhri and Ambāla obtained this season differed from that determined in 1912—13 by 0·019 of a foot. This shows the results are practically identical, and no gross error has been passed in this portion of the revisionary work.

Looking at the differences between the old and new values in the table given below, it would appear that the bench-mark at Ambāla Church referred to, may not be identical with that connected in 1860—61. It shows a settlement of 0·5 of a foot, which is difficult to reconcile considering there are no visible signs of settlement in the building. The present inscription "901·6^" did not exist when it was originally connected in 1860—61, it was inscribed afterwards by the Public Works Department, and it is possible that subsequently some alteration in the steps may have taken place. With the exception

of this bench-mark the other bench-marks show a general tendency of a gradually increasing rise from Meerut towards Ludhiāna amounting to 0·49 of a foot at the latter place, in a distance of 197 miles :—

Revision between Meerut-Ludhiāna, part of line 61.

Distance from starting Bench-mark.	Description of Bench-mark.	Height in feet above starting datum.				Difference Revised (—) original.
		Original levelling.	Year.	Revised levelling.	Year.	
Miles.		Feet.		Feet.		Foot.
0·0	At St. John's Church, Meerut, on surface of stone slab opposite north pillar of central west door-way (main entrance).	0·000	1861-62	0·000	1912-13	0·000
19·5	Khataulī Bench-mark, Stone B. M. embedded near bridge of that name, on left bank of Ganges Canal, to south-west of Meerut and Roorkee Road.	50·517	"	49·831	"	—0·686 (disturbed)
26·1	On ground level mark-stone of Begarazpur G. T. Survey Tower Station.	76·633	"	76·705	"	+0·072
32·7	Muzaffarnagar Bench-mark, Stone B. M. embedded on north side of Post Office, and near General mile post.	50·701	"	50·809	"	+0·108
48·8	Deoband Bench-mark, Stone B. M. embedded on west side, at junction of roads from Bijnor and Meerut to Deoband.	92·636	"	92·795	"	+0·159
61·4	Bhātkheri Bench-mark, subsidiary B. M. embedded on south-west side of road, about half-way between 8th and 9th milestones, near village of that name.	136·788	"	137·063	"	+0·275
72·5	Sahāranpur G. T. S. Bench-mark, embedded below ground level, 121 feet east of bridge across eastern Jumna Canal at Megh Chapar Falls, and 35 feet north of Grand Trunk Road to Ambāla, etc., etc.	167·942	"	168·012	"	+0·070
79·9	Sirsāwa Bench-mark, stone B. M. embedded in front of Sarai door-way.	157·146	"	157·265	"	+0·119
89·2	Madalpur (or Amadalpur) Bench-mark, stone B. M. embedded near bridge of that name on south side of road, and west of western Jumna Canal.	166·744	"	166·974	"	+0·230
94·8	Jagādhri Bench-mark, stone B. M. embedded at Chauki opposite encamping ground.	184·214	"	184·385	"	+0·171
125·4	901·6 /\ on upper stone step just outside wooden sill of most westerly door of St. Paul's Church, Ambāla, under tower.	162·308	"	161·793	"	—0·515
132·6	Mughal Sarai Bench-mark, stone B. M. embedded close to Trunk Road. in front of new Sarai at north-west corner of encamping ground.	149·127	1860-61	149·187	1913-14	+0·060
181·2	On ground level mark-stone of Kado G. T. Survey Tower Station.	124·731	"	125·212	"	+0·481
182·6	G. T. S. Bench-mark at Doraha, stone embedded between police chauki and Grand Trunk Road, about 1 foot below ground level, etc., etc.	104·389	"	104·833	"	+0·444
196·8	Ludhiāna Standard Bench-mark . .	68·183	1906-07	68·677	"	+0·494

Revision of levelling between Ferozepore and Lahore.—This line was originally levelled in 1866-67, and was revised to ascertain if any changes in the relative heights of bench-marks had since taken place, and also to fix a number of new bench-marks on this line, as there were very few old bench-marks in existence, most of which bore no inscriptions.

Accepting the bench-mark at Ferozepore as unaltered, the revisionary levelling shows a difference of —0·012 of a foot at the embedded bench-mark at Lahore Railway Station, and +0·081 of a foot at the Lahore Cantonment Church.

The line from Jacobābād to Quetta.—The levels were carried along the Railway line as far as Sibi traversing what is known as the "Pat" country, which is of a hard clayey soil, thence by road and railway to Rindli, after

which, except for short distances along the railway line, the main road to Quetta was followed *via* the Bolān Pass.

In the vicinity of Quetta rock cut protected bench-marks were fixed at the Murree Brewery, at Kāsī Spur, and at Shaltangi Octroi Post.

This line affords a direct connection between the Himālayas and the central Brāhui range in Baluchistān.

No. 2 Detachment.

This detachment was deputed to carry out the following programme of levelling in Bengal:—

(1) Levelling from Mymensingh to Dacca partly along the railway line and partly by road.

(2) Levelling from Howrah to Chāmpdāni by road.

(3) Levelling from Tindhāria to Darjeeling along the road.

(4) Revision of levelling from Pāchuriā to Porādaha.

(5) The revision of the river crossings:—

(*a*) Brahmaputra near Dhubri.

(*b*) Meghnā near Āshuganj.

(*c*) Lakhyā near Demra.

(*d*) Dhaleswari near Phulbāriā.

(*e*) Padmā or Ganges near Goalundo.

The line Mymensingh to Dacca.—This levelling was undertaken to connect the standard bench-mark at Mymensingh.

The work was carried partly along the railway line and partly along the main road.

The line Howrah to Chāmpdāni.—This is only part of a line of levels which will be extended to Benares, along the Grand Trunk road, in the coming field season.

The line Tindhāria to Darjeeling.—This line closed at "Observatory Hill" h. s. at Darjeeling, and is the easternmost line of levels carried into the Himālayas from the plains.

In the course of this levelling the bench-marks in Lebong and Takdah Cantonments connected during the season 1912-13, the heights of which were based on trigonometrical values, were reconnected and their true heights above mean sea level determined.

Revision of levelling from Pachuriā to Perādaha and of the river crossings.—As mentioned in the report for the last season, the circuit of levels, Porādaha-Pārvatīpur-Gauhāti-Akhaurā-Pāchuriā-Porādaha, closed with an error of 2·706 feet, the length of the circuit being 824 miles. As this error was too great for the distance levelled over, it was decided to try and locate it by revising the apparently weak portions of the circuit, which appeared to be the single levelling between Pāchuriā and Porādaha done in season 1899-1900, and the various river crossings. Originally the river crossing at Dhubri was done by the "water level" method, and those of the other rivers by the "Target" method, with the exception of the Padmā river where vertical angles were observed. In the revision for the crossing of the Padmā or Ganges river, the "Target" method was employed; for the other rivers vertical angles were observed. The results of the revision agreed closely with the values previously determined, as given in the table below:—

River and Place.	Description of Bench-marks.	Year.	Distance Across.	Method.	Difference of Height.	Mean difference of Height adopted.	Probable Error.	REMARKS.
			Miles.		Feet.	Feet.	Foot.	
Brahmaputra near Dhubri .	BOM at Queen Victoria's Statue, Dhubri to G.T.S. O B. M. in verandah of Fakirganj I. B.	1905-06 and 1913-14	2·57	"Tide Pole" "Vertical Angles"	—5·231 —4·968	—5·100	... ±0·056	
Meghnā near Āshuganj .	G.T.S. O B.M. at E distant signal of Ashuganj Ry. Stn. to G.T.S. O B.M. embedded in Kālīpur Village.	1912-13 and 1913-14	0·52	"Targets" "Vertical Angles"	—16·755 —16·534	—16·645	±0·0045 ±0·006	
Lakhyā near Demra . .	G.T.S. O B.M. on E bank of Lakhyā river to BOM at tree in Māltali village.	1912-13 and 1913-14	0·25	"Targets" "Vertical Angles"	+6·380 +6·362	+6·371	±0·0004 ±0·006	
Dhaleswari near Phulbāriā .	BOM at tree near M. P. 13 to G.T.S. O B.M. at well at Joymantab I.B.	1912-13 and 1913-14	0·51	"Targets" "Vertical Angles"	+3·019 +3·023	+3·021	±0·0034 ±0·008	
Ganges near Goalundo .	G.T.S. □ B.M. A.D. 1912 between M. P. Nos. 44 and 45 to O on referring pillar "C".	1912-13 and 1913-14	1·59	"Vertical Angles" "Targets"	+1·175 +1·151	+1·163	±0·0057 ±0·006	

The revision of the line Pāchuriā to Porādaha, by double levelling, gave a difference of 1·844 feet from the single levelling of 1899-1900.

The circuit now closes with an error of 1·086 feet as given below :—

Lines.	Distance in miles.	Difference of height in feet.	Year of Observation.
From G.T.S. □ B.M. at Porādaha Ry. Station to G.T.S. □ B.M. at Pārvatīpur	129·1	+68·096 *Vol. XIX* B	1899-1900 and 1900-1901
From G.T.S. □ B.M. at Pārvatīpur to "1895" at Gauhāti Ry. Station	228·5	+56·821	1901-02, 1905-06 & 1913-14
From "1895" at Gauhāti Ry. Station to G.T.S. □ B.M. at Akhaurā Ry. Station	283·5	—152·342	1910-11 and 1911-12
From G.T.S. □ B.M. at Akhaurā Ry. Station to G.T.S. □ Minor. B.M. at Pāchuriā Ry. Station	136·8	+9·588	1911-12, 1912-13 & 1913-14
From G.T.S. □ Minor B.M. at Pāchuriā Ry. Station to G.T.S. □ B.M. at Porādaha Ry. Station	45·6	+18·923	1913-14
TOTAL .	823·5	+1·086	...

It is likely that a great portion of this error falls in the hill section from Gauhāti, *viâ* Dumpep, to Tharia Ghāt, which has a rise of 5,917 feet in a distance of 81 miles, and a fall of 5,976 feet in a distance of 25 miles.

No. 3 Detachment.

The following programme of work in Burma was allotted to the detachment :—

(1) Levelling from Thazi to Taunggyi, partly along the railway line and partly by road.

(2) Levelling from Magwe to Taungdwingyi along the road.

(3) Levelling from Mokpalin to Amherst by road.

The line Thazi to Taunggyi.—This is a line from the plains to the hills. The line of levels was carried along the railway line from Thazi to Yinmabin, and thence along the Public Works Department unmetalled road *viâ* Kalaw, Hsamönghkam to Taunggyi, where the Standard bench-mark was connected.

The line Magwe to Taungdwingyi.—This line completes the circuit Rangoon-Meiktila-Magwe-Taungdwingyi-Prome-Rangoon, the first in Burma. The closing error being 0·287 of a foot in 882 miles as given below:—

Lines.	Distance in miles.	Observed difference of elevation in feet.	Year.
From Standard bench-mark at Cantonment Gardens, Rangoon to G. T. S. □ B. M. A. D. 1892. at Thazi (Meiktila Road) Railway Station.	301·3	+421·417	1903-04 and 1909-10.
From G. T. S. □ B. M. A. D. 1892. at Thazi (Meiktila Road) Railway Station to Standard bench-mark, Magwe.	135·6	—358·211	1902-03 and 1909-10.
From Standard bench-mark, Magwe, to G. T. S. □ B. M. A. D. 1911. at P. W. D. Inspection Bungalow at Taungdwingyi.	63·8	+275·357	1913-14.
From G. T. S. □ B. M. A. D. 1911. at P. W. D. Inspection Bungalow at Taungdwingyi to Standard bench-mark at District Court House, Prome.	111·7	—321·907	1912-13.
From Standard bench-mark at District Court House, Prome. to Standard bench-mark at Cantonment Gardens, Rangoon.	269·7	—16·369	1911·1912
TOTAL . .	882·1	+0·287	...

The line Mokpalin to Amherst.—This completes the line from Pegu to Amherst. The line follows the west embankment of the Sittang Canal up to Kyaikto, and thence the Public Works Department unmetalled road to Martaban.

At Martaban the levels were carried across the Salween river by vertical angle observations, thence by the Public Works Department road *viâ* Mudon and Kwanhla to Amherst.

General Notes.

Outturn of Work.—The combined Tabular Statement of the three detachments shows the outturn of work of the party.

Standard Bench-marks.—The Standard Bench-marks at Mymensingh, Quetta, Taunggyi and Moulmein were connected during the field season.

Methods of taking the levels across the various rivers.—During the season under report, levels were carried across the following rivers:—

By the "*Vertical Angle*" method.

(1) Brahmaputra, at Dhubri in Assam.

(2) Meghnā, at Āshuganj in Bengal.

(3) Lakhyā, at Demra in Bengal.

(4) Dhaleswari, at Phulbāriā in Bengal.

(5) Salween, at Moulmein in Lower Burma.

By the "*Target Method.*"

(6) Padmā or Ganges river, at Goalundo in Bengal.

In the first four crossings the instruments used were eight-inch micrometer theodolites, No. 12616 by T. Cooke and Sons and No. 1056 by Troughton and Simms.

The direct distances between the stations on opposite banks, obtained by triangulation, were as follows:—

On the Brahmaputra	2·57 miles
„ Meghnā	0·52 „
„ Lakhyā	0·25 „
„ Dhaleswari	0·51 „

The signals consisted of the backs of 6-inch heliotropes, the surface of which was divided into four quadrants painted black and white alternately to admit of accurate intersection.

The positions of the Theodolite stations were marked by large wooden pegs firmly driven flush with the ground, which were connected by spirit levelling with permanent bench-marks on both banks. Check levelling was carried out twice daily between these peg stations and the permanent bench-marks, once before the observations were started, and again after the close of the observations.

Simultaneous reciprocal vertical angles were taken by two observers, one on each bank, at intervals from 9 A.M. to 3 P.M. on several days, and the mean results obtained from all the observations were adopted in every case.

The probable errors of observation were as follows:—

	Feet.
At the Brahmaputra	± 0·056
„ Meghnā	± 0·006
„ Lakhyā	± 0·006
„ Dhaleswari	± 0·008

In crossing the Salween river between Martaban and Moulmein, the instruments employed were eight-inch micrometer theodolites No. 12617 by T. Cooke and Sons, and No. 1091 by Troughton and Simms.

Two permanent bench-marks were constructed, one on each bank, which formed the stations of observation. The direct distance between these bench-marks was determined by triangulation, and worked out to 1·5 miles.

The signals observed to were 6-inch heliotropes, the object intersected being the inner 3-inch diameter surface, the remainder of the disc being covered with black paper.

Simultaneous reciprocal observations were taken by two observers between 7·30 and 10 A.M., and again between 1 and 3·30 P.M., on four days, and the mean of the results obtained from all the observations was adopted. The probable error was ± 0·011 of a foot.

The crossing of the Padmā or Ganges river at Goalundo was done by the "Target" Method. The targets used were exactly of the same pattern as described on page 72 of the Records of the Survey of India, Volume V, and the general procedure adopted in the crossing was practically the same as previously followed. The distance between the marks on the opposite banks was 1·6 miles as determined by triangulation.

Observations were taken by two observers with two levels on three days, in the mornings and afternoons, the number of sets taken being 118. The mean result of these sets was adopted. The probable error was ± 0·006 of a foot.

M 2

New type of embedded bench-mark.—This bench-mark consists of a well galvanized iron pipe with a solid zinc cap machined, screwed and rivetted on the top of it, and with four flanges fixed at the bottom. It is 4 inches in diameter and 3 feet long, embedded $2\frac{1}{4}$ feet in rammed earth with 8 inches projecting and rests on a bed of concrete one foot square and 2 inches thick. The top surface of the cap bears an inscription G. T. SURVEY O BENCH MARK and is about 1 foot 7 inches below ground level. The pipe is enclosed by a hollow 3 bricked vault $5\frac{1}{2}$ feet by $4\frac{1}{2}$ feet and with a central radius of 2 feet $6\frac{1}{2}$ inches. The brickwork of the vault rests on concrete. Vertically above the pipe there is an aperture 6 inches square at the crown of the vault. Over this aperture is a hollow masonry pillar, carrying a mark-stone with the words G. T SURVEY O UPPER MARK inscribed on it.

The whole structure is built under ground, except the upper mark-stone which is a few inches above ground level. The upper surface of the earth-filling over the vault is sloped downwards from the mark-stone to drain off rain water.

Tree Bench-marks.—At the request of the Forest Department, experiments with tree bench-marks are being carried out in the compound of the Head-Quarters of the Trigonometrical Survey, Dehra Dūn, with a view of settling the question of whether or not tree stems are gradually raised bodily during the process of growth.

Several trees of different kinds and ages have been selected, and zinc plates bearing the inscription G. T. S. O B. M. fixed, some on the surface, some where the bark has been removed, and some into the heart wood of the trunks of trees, and also on the roots of some trees. Check levelling to these bench-marks will be done twice yearly, once in April and once in October, *i.e.*, just before and after the period of greatest vegetative activity. The experiments will be continued for some years. No appreciable change, at present, has been noticed in the constancy of elevation of the bench-marks in question during the year under report.

New system of levelling.—The present system of levelling of precision in India is that initiated by General Walker in 1858. It is "Simultaneous double levelling." In this system each line is observed by two levellers working independently under practically identical conditions. Each line is divided into a number of sections, and the total length of the sections levelled in one direction is made equal to that of those that are levelled in the opposite direction.

At the International Geodetic Conference of 1912, a resolution was passed that in future there should be a new category of levelling to be called "Levelling of high precision," and that to qualify for this category each section of a line of levels must be levelled independently in both the forward and the backward direction on dates as widely different as possible, andthat the errors claculated according to certain formulæ must not exceed certain limits.

The main object of this new system is to evaluate the systematic or cumulative error dependent on the direction in which the levellers move. In the "Simultaneous double levelling" this error cannot be evaluated, because every section is worked in the same direction and not fore and back by both levellers: it is however eliminated from the final result by the system of levelling alternate sections in opposite directions.

During the past season two lines were worked on the new system of "fore and back double levelling" *viz.:*—

Ferozepore to Lahore, and Jacobābād to Quetta—Each section was, however, levelled on the same day, a plan, which though not quite in accordance with the above resolution, has several points in its favour.

Henceforward the system of "fore and back double levelling" will always be employed.

TABLE I—No. 1 DETACHMENT.

Tabular Statement of Outturn of Work, Season 1913-14.

Section.	Month.	Number of miles of double levelling. Line.	Extras and branch line.	Total.	Total number of feet. Rises.	Falls.	Number of stations at which instrument was set up.	Number of bench-marks connected. Primary. Rock-cut protected.	Standard.	Principal station of triangulation.	Old.	Secondary. Old.	Embedded.	Rock-cut.	Inscribed.	Irrigation.	Railway.	P. W. D.	Tertiary hill stations.	Remarks.
		Mls. chs. lks.	Mls. chs. lks.	Mls. chs. lks.	Feet.	Feet.														
Solon—Simla	November 1913	31 26 92	4 35 8	35 62 0	3648·273	830·267	999	6	...	...	1	3	...	50	8	...	...	2	2	
	TOTALS	31 26 92	4 35 8	35 62 0	3648·273	830·267	999	6	...	...	1	3	...	50	8	...	...	2	2	
Revision of Ambāla-Jagādhri.	December 1913	30 56 86	6 50 22	37 27 8	184·502	160·618	393	...	...	...	1	42	...	...	3	...	...	1	...	
	TOTALS	30 56 86	6 50 22	37 27 8	184·502	160·618	393	...	...	...	1	42	...	...	3	...	...	1	...	
Revision of Ferozepore-Lahore.	December 1913	6 9 36	4 67 68	10 77 4	54·052	17·072	132	...	...	...	1	17	...	...	6	...	...	2	...	
	January 1914	48 51 32	9 29 24	58 0 56	347·270	323·535	630	...	...	...	1	44	4	...	31	12	4	...	...	
	TOTALS	54 60 68	14 16 92	68 77 60	401·322	340·607	762	...	...	...	2	61	4	...	37	12	4	2	...	
Revision of Ambāla-Ludhiāna.	January 1914	30 11 20	0 33 70	30 44 90	166·747	192·705	278	...	...	...	...	3	...	...	25	...	...	...	...	*Includes one old principal station of triangulation re-connected.
	February „	41 24 32	3 32 52	44 56 84	125·036	192·185	427	...	...	1	*2	12	...	...	39	...	...	2	...	
	TOTALS	71 35 52	3 66 22	75 21 74	291·783	384·890	705	...	...	1	2	15	...	...	64	...	...	2	...	
Jacobābād-Quetta	February 1914	36 12 42	0 61 36	36 73 78	146·491	92·565	372	...	...	...	1	7	3	...	26	...	26	1		
	March „	88 15 98	1 18 98	89 29 96	889·946	329·839	863	...	...	...	...	...	10	2	65	...	54	...	...	
	April „	55 53 22	0 0 0	55 53 22	5650·132	569·844	997	4	...	...	...	...	6	53	28	...	2	...	...	
	May „	26 49 18	5 57 34	32 26 52	1104·388	664·024	390	3	1	...	...	...	2	...	36	...	1	1	...	
	TOTALS	206 50 80	7 52 68	214 23 48	7790·957	1656·272	2622	7	1	...	1	7	21	55	155	...	83	2	...	
	GRAND TOTALS	394 70 78	36 61 12	431 51 90	12316·837	3372·654	5481	13	1	1	7	128	25	105	267	12	87	9	2	

TABLE I—(*continued*)—No. 2 DETACHMENT.

Tabular Statement of Outturn of Work, Season 1913-14 —continued.

Section.	Month.	Number of miles of double levelling. Line.	Extras and Auxiliary.	Total.	Total number of feet. Rises.	Falls.	Number of stations at which instrument was set up.	Number of bench-marks connected. Primary. Standard. Old.	New.	Secondary. Embedded. Old.	New.	Rock-cut. Old.	New.	Inscribed. Old.	New.	Zinc plates.	Metal bolts.	Secondary Station of "Δ."	Railway.	Remarks.
		Mls. chs. lks.	Mls. chs. lks.	Mls. chs. lks.	Feet.	Feet.														
Mymensingh to Dacca	November 1913	2 60 24	...	2 60 24	8·608	16·395	32	...	1	...	1	...	...	...	3	...	...	...	...	
	December „	76 76 88	4 73 88	81 70 76	490·850	519·599	902	...	...	...	9	..	...	...	44	17	3	...	...	
	January 1914	7 17 78	...	7 17 78	58·807	51·553	82	1	...	1	..	...	...	2	3	1	2	...	...	
	TOTALS	86 74 90	4 73 88	91 68 78	561·265	587·547	1,016	1	1	1	10	...	...	2	50	18	5	...	...	
Connection of Bhairab Embedded B. M.	January 1914	0 4 0	...	0 4 0	3·990	9·113	4	...	...	...	1	...	.	2	...	...	...	...	...	
Pāchuriā to Porādaha	February „	40 67 90	...	40 67 90	194·965	176·532	410	...	..	5	...	...	...	22	5	...	...	...	..	
	March „	6 43 14	...	6 43 14	30·198	37·351	66	...		1	...	.	...	5	...	...	..	...	...	
	TOTALS	47 31 4	...	47 31 4	225·163	213·883	476	..	...	6	...	...	...	27	5	...	...	..	...	
Howrah to Benares	March 1914	28 1 68	0 17 92	28 19 60	194·747	184·619	294	...	...	3	2	..	...	6	25	2	...	...	...	
	TOTALS	28 1 68	0 17 92	28 19 60	194·747	184·619	294	...	...	3	2	...	...	6	25	2	...	...	...	
Tindhāria to Darjeeling	April 1914	32 47 48	1 16 40	33 63 88	5100·512	643·757	936	...	...	...	...	1	22	1	19	...	...	1	2*	*Old B. Ms. re-connected.
	May „	0 35 62	12 67 42	13 23 4	206·567	2·601	625	...	...	...	...	...	4	...	19	...	...	2	...	
	TOTALS	33 3 10	14 3 82	47 6 92	5307·079	646·358	1,561	...	...	...	...	1	26	1	38	...	...	3	2	
	GRAND TOTALS	195 34 72	19 15 62	214 50 34	6292·244	1641·520	3,851	1	1	10	13	1	26	38	118	20	5	3	2	

TABLE I—(*concluded*)—No. 3 DETACHMENT.

Tabular Statement of Outturn of Work, Season 1913-14—(concluded).

Section.	Month.	Number of miles of double levelling. Line.	Extras and Auxiliary.	Total.	Total number of feet. Rises.	Falls.	Number of stations at which instrument was set up.	Number of bench-marks connected. Primary. Rock-cut protected.	Standard.	Secondary. Embedded.	Rock-cut.	Inscribed.	Zinc-plates.	Metal bolt.	Tidal.	Remarks.
		Mls. chs. lks.	Mls. chs. lks.	Mls. chs. lks.	Feet.	Feet.										
Taunggyi-Thazi	November 1913	1 24 80	0 66 4	2 10 84	5·572	155·992	58	1	1	...	..	...	...	...	...	
	December „	40 61 14	... ..	40 61 14	2795·059	3323·484	1,006	...	...	4	5	2	...	...	...	
	January 1914	52 43 78	3 5 58	55 48 36	1148·096	4652·697	1,103	...	...	6	6	9	...	...	..	
	TOTALS	94 48 72	3 71 62	98 40 34	3948·727	8132·173	2,167	1	1	10	11	11	...	..	...	
Magwe-Taungdwingyi	February 1914	52 11 36	2 59 40	54 70 76	1631·527	1363·618	748	...	1	6	...	10	2	...	...	
	March „	11 53 86	0 5 80	11 59 66	134·911	127·250	128	...	...	1	...	3	2	...	..	
	TOTALS	63 65 22	2 65 20	66 50 42	1766·438	1490·868	876	...	1	7	...	13	4	...	...	
Mokpalin-Amherst	March 1914	58 31 48	0 75 16	59 26 64	1347·990	1359·563	895	...	...	8	1	8	5	1	...	
	April „	58 19 89	1 10 14	59 30 3	929·370	944·556	772	...	1	8	8	12	...	...	2	
	May „	36 79 84	0 10 6	37 9 90	1005·699	1002·449	496	...	...	3	...	1	...	...	1	
	TOTALS	153 51 21	2 15 36	155 66 57	3283·059	3306·568	2,163	...	1	19	9	21	5	1	3	
	GRAND TOTALS	312 5 15	8 72 18	320 77 33	8998·224	12929·609	5,206	1	3	36	20	45	9	1	3	

TABLE II—No. 1 DETACHMENT.

Discrepancies between the Old and New Heights of Bench-marks.

Description of bench-marks of the original levelling that were connected for check-levelling.	Distance from starting bench-mark.	Observed height above (+) or below (−) starting bench-mark as determined by					Difference (Check—Original). The sign + denotes that the height was greater and the sign − less in check-levelling than when originally levelled.			Remarks.
		Original levelling.	Date.	*Check-levelling.*						
				1910-11.	1912-13.	1913-14.	1910-11.	1912-13.	1913-14.	
	Miles.	Feet.		Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	
Check-levelling at Ambāla, part of line 61 (Ferozepore—Meerut).										
901·6/\ At St. Paul's Church, Ambāla.	0·0	0·000	1860-61	0·000	0·000	0·000	0·000	0·000	0·000	
† At ditto ditto	0·1	+0·503	1906-07	+0·515	+0·512	+0·513	+0·012	+0·009	+0·010	
Standard Bench-mark, Ambāla	0·1	+1·829	1906-07	+1·827	+1·820	+1·825	−0·002	−0·009	−0·004	
G. T. S. O R. M. At Block No. 6, Station Hospital, Ambāla.	0·4	+0·029	1906-07	not connected.	+0·077	+0·083	not connected.	+0·048	+0·054	
G. T. S. O B. M. At Wesleyan Church, Ambāla.	1·0	+3·704	1906-07	+3·740	+3·737	+3·757	+0·036	+0·033	+0·053	
G. T. S. O B. M. At Block No. 3 of No. 2, Section Hospital, Ambāla.	1·2	+4·969	1906-07	+5·009	+5·002	+5·019	+0·040	+0·033	+0·050	

G. T. S. O B. M.	At Block No. 2 of No. 2, Section Hospital, Ambāla.	1·2	+4·103	1906-07	+4·139	+4·133	+4·149	+0·036	+0·030	+0·046
G. T. S. O B. M.	At Block No. 42 R. H. A. Lines, Ambāla.	1·9	+10·090	1906-07	+10·123	+10·114	+10·135	+0·033	+0·024	+0·045
G. T. S. O B. M.	At Block No. 43 R. H. A. Lines, Ambāla.	2·0	+11·484	1903-07	+11·498	+11·479	+11·500	+0·002	+0·021	+0·016
†	At R. C. Church, Ambāla .	1·0	−3·044	1906-07	not connected.	−3·046	−3·030	not connected.	−0·002	+0·014
G. T. S. O B. M.	At ditto ditto .	1·1	−3·618	1906-07	Do.	−3·611	−3·595	Do.	+0·007	+0·023
G. T. S. O B. M.	At N. W. end of "B" platform, Ambāla Cantonment Railway Station.	1·7	−2·667	1906-07	−2·620	−2·636	−2·622	+0·047	+0·031	+0·045
G. T. S. O B. M.	At N. W. name plate on "A" platform of Ambāla Railway Station.	1·7	−3·078	1906-07	not connected.	not connected.	−3·106	not connected.	not connected.	−0·028
G. T. S. O B. M.	At S. E. name plate on "A" platform of Ambāla Railway Station.	1·8	−3·532	1906-07	−3·498	−3·513	−3·501	+0·034	+0·019	+0·031

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TABLE II—(*continued*).—No. 1 DETACHMENT.

Discrepancies between the Old and New Heights of Bench-marks—continued.

Description of bench-marks of the original levelling that were connected for check-levelling.	Distance from starting bench-mark.	Observed height above (+) or below (—) starting bench-mark as determined by			Difference (Check-Original). The sign + denotes that the height was greater and the sign — less in 1913-14 than when originally levelled.	Remarks.
		Original levelling.	Date.	Check-levelling, 1913-14.		
	Miles.	Feet.		Feet.	Feet.	
Check-levelling at Solon, part of line 61F (Ambāla-Solon).						
G. T. S. O. B. M. At rock *in situ* near Roman Catholic Chapel, Solon.	0·0	0·000	1910-11	0·000	0·000	
G. T. S. O. B. M. At rock *in situ* on path below Roman Catholic Chapel, Solon.	0·2	+27·749	1910-11	—27·734	—0·015	
G. T. S. O. B. M. At rock *in situ* at junction of roads to Dâk and inspection bungalow.	0·6	—59·806	1910-11	—59·813	—0·007	
G. T. S. O. B. M. At rock *in situ* 193 feet South-West of F. S. $\frac{20}{1}$.	1·4	—120·641	1910-11	—120·636	+0·005	
Check-levelling at Jagādhri, part of line 61 (Ferozepore-Meerut).						
G. T. S. □ B. M. At Thana and Tahsil, Jagādhri.	0·0	0·000	1912-13	0·000	0·000	
⊼ At Bridge No. 42 . .	0·1	—1·512	1912-13	+1·493	+0·019	
⋀ At well between miles 39 and 40 Ambāla.	0·5	—1·340	1912-13	—1·328	+0·012	
⋀ At well in front of *Gaushala*, Jagādhri.	0·6	—1·519	1912-13	—1·517	+0·002	
⋀ At bridge No. 44 . .	0·9	—0·743	1912-13	—0·742	+0·001	
At well near police chowki at junction of roads to Būriya and Jagādhri City, Railway Station.	1·3	+3·063	1912-13	+3·083	+0·020	
At bridge 8 chains North of police chowki.	1·5	+0·994	1912-13	+1·010	+0·016	
⊼ At well at junction of roads to Jagādhri, Railway Station, Būriya and Madalpur.	1·9	+5·100	1910-11	+5·130	+0·030	
Check-levelling at Ferozepore, part of line 56 (Ferozepore-Chach).						
G. T. S. Stone B. M. at Ferozepore	0·0	0·000	1866-67	0·000	0·000	
Standard Bench-mark at Ferozepore	0·3	+4·179	1906-07	+4·194	+0·015	
G. T. S. O B. M. On S. door of Sāragarhi Memorial, Ferozepore.	0·4	+5·824	1906-07	+5·832	+0·008	
G. T. S. O B. M. On W. door of Sāragarhi Memorial, Ferozepore.	0·5	+2·788	1906-07	+2·794	+0·006	
G. T. S. O B. M. On main platform, Ferozepore Cantonment Railway Station.	1·2	+7·352	1906-07	+7·340	—0·012	
G. T. S. O B. M. On island platform, Ferozepore Cantonment Railway Station.	1·4	+8·925	1906-07	+8·887	—0·038	

TABLE II—(*continued*).—No. 1 DETACHMENT.

Discrepancies between the Old and New Heights of Bench-marks—continued.

Description of bench-marks of the original levelling that were connected for check-levelling.	Distance from starting bench-mark.	OBSERVED HEIGHT ABOVE (+) OR BELOW (—) STARTING BENCH-MARK AS DETERMINED BY			Difference (Check-Original). The sign + denotes that the height was greater and the sign — less in 1913-14 than when originally levelled.	REMARKS.
		Original levelling.	Date.	Check-levelling, 1913-14.		
	Miles.	Feet.		Feet.	Feet.	
Check-levelling at Ferozepore, part of line 56 (Ferozepore-Chach)—contd.						
G. T. S. O B. M. On Public Dâk bungalow, Ferozepore.	0·7	+1·739	1906-07	+1·742	+0·003	
G. T. S. O B. M. On main entrance, St. Andrew's Church, Ferozepore.	1·4	+3·979	1906-07	+3·997	+0·018	
G. T. S. O B. M. On Sutlej Campaign Memorial, Ferozepore.	1·4	+5·483	1906-07	+5·494	+0·011	
G. T. S. O B. M. On Wesleyan Church, Ferozepore.	1·7	+2·703	1906-07	+2·697	—0·006	
G. T. S. O B. M. On block No. 9, at Station Hospital.	2·4	+6·558	1906-07	+6·530	—0·028	
G. T. S. O B. M. On block No. 5, at Station Hospital.	2·5	+6·513	1906-07	+6·492	—0·021	
G. T. S. O B. M. On block No. 2 barrack, British Infantry line.	2·7	+5·246	1906-07	+5·250	+0·004	
G. T. S. O B. M. On block No. 3 R. H. A. lines, E. of door No. 18.	3·2	+4·499	1906-07	+4·511	+0·012	
G. T. S. O B. M. On block No. 3 R. H. A. lines, opposite door No. 18.	3·2	+4·335	1906-07	+4·339	+0·004	
G. T. S. O B. M. Near door No. 48 of double-storied building in Fort.	1·7	+11·078	1906-07	+11·052	—0·026	
G. T. S. O B. M. At N. E. end of N. W. verandah of above building in Fort.	1·6	+11·402	1906-07	+11·386	—0·016	
G. T. S. O B. M. At drain near W. gate of Arsenal.	1·6	+4·247	1906-07	+4·212	—0·035	
Check-levelling between Ludhiāna and Doraha, part of line 61 (Ferozepore-Meerut).						
Standard Bench-mark at Ludhiāna .	0·0	0·000	1906-07	0·000	0·000	
G. T. S. O B. M. At door of Church of England, Ludhiāna.	0·0	—0·883	1906-07	—0·880	+0·003	
G. T. S. O B. M. At District Judge's Court, Ludhiāna.	0·2	+1·085	1906-07	+1·091	+0·006	
G. T. S. O B. M. At Deputy Commissioner's Court, Ludhiāna.	0·4	+3·916	1906-07	+3·924	+0·008	

TABLE II—(*continued*).—No. 1 DETACHMENT.

Discrepancies between the Old and New Heights of Bench-marks—continued.

Description of bench-marks of the original levelling that were connected for check-levelling.	Distance from starting bench-mark.	Observed height above (+) or below (—) starting bench-mark as determined by: Original levelling.	Date.	Check-levelling, 1913-14.	Difference (Check-Original). The sign + denotes that the height was greater and the sign — less in 1913-14 than when originally levelled.	Remarks.
	Miles.	Feet.		Feet.	Feet.	
Check-levelling between Ludhiāna and Doraha, part of line 61 (Ferozepore-Meerut)—concld.						
G. T. S. O B. M. At clock tower, Ludhiāna	0·6	+1·633	1906-07	+1·626	—0·007	
G. T. S. O B. M. At island platform at N. end, Ludhiāna Railway Station.	0·9	+3·148	1906-07	+3·160	+0·012	
G. T. S. O B. M. At island platform at S. end, Ludhiāna Railway Station.	1·0	+3·234	1906-07	+3·243	+0·009	
G. T. S. O B. M. At bridge No. 402	3·9	+15·447	1906-07	+15·422	—0·025	
G. T. S. O B. M. At „ „ 401	5·9	+26·308	1906-07	+26·309	+0·001	
G. T. S. O B. M. At „ „ 400	9·5	+33·641	1906-07	+33·628	—0·013	
G. T. S. O B. M. At „ „ 399	10·5	+35·521	1906-07	+35·512	—0·009	
G. T. S. Stone B. M. at Doraha	14·2	+36·204	1906-07	+36·156	—0·048	Probably settled.
G. T. S. O B. M. At bridge over Sirhind Canal.	14·2	+52·331	1906-07	+52·276	—0·055	Do.
Check-levelling at Jacobābād, part of line 54A [Shikārpur (Sind)—Jacobābād].						
Standard Bench-mark at Jacobābād	0·0	0·000	1909-10	0·000	0·000	
Iron plug at Executive Engineer's Office, Jacobābād.	0·0	—1·420	1909-10	—1·420	0·000	
G. T. S. O B. M. At Victoria clock tower at Jacobābād.	0·5	+2·740	1909-10	+2·736	—0·004	
G. T. S. O B. M. At Municipal Office at Jacobābād.	0·9	—0·738	1909-10	—0·761	—0·023	
G. T. S. O B. M. At Lang Shāh's *takia* at Jacobābād.	1·0	+0·660	1909-10	+0·672	+0·012	
G. T. S. □ B. M. At Jacobābād Railway Station.	1·4	—6·026	1909-10	—6·011	+0·015	
G. T. S. O B. M. At Railway bridge No. 83	1·9	+3·485	1909-10	+3·510	+0·025	
G. T. S. O B. M. At Stone coping of platform of Jacobābād Railway Station.	1·5	+2·109	1909-10	+2·121	+0·012	

TABLE II—(*continued*).—No. 2 DETACHMENT.

Discrepancies between the Old and New Heights of Bench-marks—continued.

Description of bench-marks of the original levelling that were connected for check-levelling.	Distance from starting bench-mark.	Observed height above (+) or below (—) starting bench-mark as determined by: Original levelling.	Date.	Check-levelling, 1913-14.	Difference (Check-Original). The sign + denotes that the height was greater and the sign — less in 1913-14 than when originally levelled.	Remarks.
	Miles.	Feet.		Feet.	Feet.	
Check-levelling at Dacca, part of line 77-I (Akhaurā to Dacca).						
Standard Bench-mark at Dacca	0·0	0·000	1912-13	0·000	0·000	
O On fountain at Government house, Dacca.	0·5	—3·373	1912-13	—3·366	+0·007	
G. T. S. O B. M. At Dacca College	0·7	—4·635	1912-13	—4·629	+0·006	
G. T. S. □ B. M. A. D. 1912. Ditto	0·9	—0·411	1912-13	—0·413	—0·002	
Revision between Howrah and Chāmpdāni, parts of lines 75 (Kendrāpāra to Howrah) and 75-B (Howrah to Nadiā).						
G. T. S. O B. M. In Government Botanical Gardens, Howrah.	0·0	0·000	1881-82 and 1882-83	0·000	0·000	
G. T. S. O B. M. Near Burn & Co.'s Workshop, Howrah.	4·2	+1·232	1881-82 and 1882-83	+1·224	—0·008	
G. T. S. O B. M. 82-83 At bridge over Bally creek.	10·3	+8·517	1882-83 and 1887-88	+8·487	—0·030	
G. T. S. O B. M. At steps of Uttarpāra Public Library.	10·8	+5·366	1882-83 and 1887-88	+5·414	+0·048	
G. T. S. O B. M. At house of Raja Piyari Mohan Mukherjee.	11·7	+7·880	1882-83 and 1887-88	+7·929	+0·049	
G. T. S. O B. M. At Konnagar (12 temple) *ghāt*.	14·1	+1·623	1882-83 and 1887-88	+1·713	+0·090	
G. T. S. O B. M. At parapet of bridge ½ mile north of Seorāphulī Bazar.	20·8	+6·681	1882-83 and 1887-88	+6·795	+0·114	
Check-levelling at Tindhāria, part of line 77-E (Silīgurī to Tindhāria).						
G. T. S. O B. M. On bed rock near road bridge No. 90.	0·0	0·000	1909-10	0·000	0·000	
G. T. S. O B. M. On rock near Loco. Superintendent and Sub-Divisional Officer's Bungalow, Tindhāria.	1·4	+243·832	1909-10	+243·841	+0·009	
Metal bolt at W end of Tindhāria Railway Station.	1·8	+321·653	1909-10	+321·663	+0·010	
Metal bolt at N end of Tindhāria Railway Station.	1·9	+321·652	1909-10	+321·662	+0·010	

TABLE II—*continued.*—No. 3 DETACHMENT.

Discrepancies between the Old and New Heights of Bench-marks—continued.

Description of bench-marks of the original levelling that were connected for check-levelling.	Distance from starting bench-mark.	Observed height above (+) or below (—) starting bench-mark as determined by			Difference (Check-Original). The sign + denotes that the height was greater and the sign — less in 1913-14 than when originally levelled.	Remarks.
		Original levelling.	Date.	Check levelling 1913-14.		
	Miles.	Feet.		Feet.	Feet.	
Check-levelling at Thazi, part of Provisional line No. 87 (Elephant Point to Myitkyinā).						
G. T. S. ☐ B. M. A.D. 1892. At Thazi Railway Station	0·0	0·000	1903-04	0·000	0·000	
G. T. S. O B. M. On E. side of drain No. 607	1·7	—4·978	1903-04	—5·031	—0·053	Damaged.
G. T. S. O B. M. On E. side of drain No. 610.	2·9	+3·974	1903-04	+4·046	+0·072	
G. T. S. O B. M. On N. end of E. parapet of culvert No. 594.	1·3	—1·800	1903-04	—1·720	+0·080	
Check-levelling at Taungdwingyi, part of Provisional line No. 88 (Thazi to Prome and Rangoon).						
G. T. S. ☐ B. M. A. D. 1911. At Taungdwingyi P. W. D. I. B.	0·0	0·000	1912-13	0·000	0·000	
G. T. S. O B. M. At N. parapet of culvert No. $\frac{1}{1}$ on Magwe road.	0·1	+5·026	1912-13	+4·988	—0·038	
G. T. S. O B. M. On top of concrete post 2 feet N. of M. P. O.	0·1	+2·435	1912-13	+2·416	—0·019	
G. T. S. O B. M. On top of concrete post 3½ feet E. of M. P. I.	1·1	—6·148	1912-13	—6·166	—0·018	
G. T. S. O B. M. On trunk of tree 107 feet from M. P. 3.	3·1	—20·772	1912-13	—20·803	—0·031	
Check-levelling at Mokpalin, part of line No. 87A (Pegu to Moulmein and Amherst).						
G. T. S. ☐ B. M. A. D. 1912. At Mokpalin P.W.D., I.B.	0·0	0·000	1912-13	0·000	0·000	
G. T. S. ☐ B. M. A. D. 1912. At Mokpalin Railway Station.	0·6	+18·178	1912-13	+18·167	—0·011	
G. T. S. O B. M. At platform coping of Mokpalin R. S.	0·4	+7·673	1912-13	+7·667	—0·006	
Plug at S. E. abutment of Mokpalin lock of Kyaikto Canal.	0·2	—4·283	1912-13	—4·285	—0·002	
G. T. S. O B. M. On N. masonry seat of landing on Kyaikto Canal.	0·0	—6·093	1912-13	—6·094	—0·001	
B. O. M. On S. parapet of Bridge No. 36.	0·4	+0·860	1912-13	+0·860	0·000	
G. T. S. O B. M. On N. abutment of Bridge No. 37.	0·9	—4·237	1912-13	—4·243	—0·006	

TABLE II—(*concluded*).—No. 3 DETACHMENT.

Discrepancies between the Old and New Heights of Bench-marks—concluded.

Description of bench-marks of the original levelling that were connected for check-levelling.	Distance from starting bench-mark.	Observed height above (+) or below (—) starting bench-mark as determined by				Difference (Check-Original). The sign + denotes that the height was greater and the sign — less in check-levelling than when originally levelled.		Remarks.
		Original levelling.	Date.	Check-levelling. 1909-10.	Check-levelling. 1913-14.	1909-10.	1913-14.	
	Miles.	Feet.		Feet.	Feet.	Feet.	Feet.	
Check-levelling at Magwe part of Provisional line No. 88 (Thazi to Prome and Rangoon).								
G. T. S. □ B. M. At Magwe. A. D. 1902.	0·0	0·000	1902-03	0·000	0·000	0·000	0·000	The embedded bench-mark at Magwe (Myo-haung) appears to have risen.
Standard Bench-mark at Magwe.	1·7	—74·298	1902-03	—74·305	—74·412	—0·007	—0·114	
G. T. S. □ B. M. At Gymkhana Club, Magwe.	2·0	—73·424	1902-03	—73·395	—73·493	+0·029	—0·069	
G. T. S. O B. M. At culvert 6¼ chains S. of Magwe I. B.	1·9	—75·387	1902-03	—75·394	—75·500	—0·007	—0·113	
G. T. S. O B. M. At Culvert W. of Civil Police barracks.	0·8	—76·798	1902-03	—76·798	—76·872	0·000	—0·074	

TABLE III.

List of Great Trigonometrical Survey Stations connected by Spirit-levelling, Season 1913-14.

No. of Detachment.	Name of Station.	Height above Mean Sea level by Spirit levelling.	Height above Mean Sea level by Triangulation.	Difference Levelling—Triangulation.	Remarks.
		Feet.	Feet.	Feet.	
No. 1 Detachment	Kūmra T. S., Rahun meridional series.	873·615	873	—0·615	Height of ground level mark-stone.
	Kado T. S., Rahun meridional series.	863·584	863·159*	—0·425	Height of ground level mark-stone.
No. 2 Detachment	Kurseong h. s., North-East Longitudinal series.	4,623·629	4,540	+16·371	Height of upper mark-stone.
	Darjeeling observatory h. s., North-East Longitudinal series.	7,144·940	7,162	+17·060	Height of upper mark-stone.
	Takdah h. s., North-East Longitudinal series.	6,746·516	6,758	+11·484	Height of lower mark-stone.

* Orthometric height as shewn in Volume XIX B of levelling operations.

TABLE IV.

Difference between levellers.

Number of Detachment.	Section.	Difference.	First—Second.
			Feet.
No. 1 Detachment.	Line Solon-Simla . .	At 31¼th mile or end of line .	−0·121
	Revision of Ambāla-Jagādhri.	" 30¾th " " " .	−0·063
	Revision of Ferozepore-Lahore.	" 50th " . . .	−0·003
	Ditto . .	" 55th " or end of line .	+0·013
	Revision of Ambāla-Ludhiāna.	" 50th " . . .	+0·018
	Ditto .	" 71⅓th " or end of line .	+0·051
	Line Jacobābād-Quetta .	" 50th " . . .	+0·053
	Ditto . .	" 100th " . . .	+0·049
	Ditto . .	" 150th " . . .	+0·0[illegible]3
	Ditto . .	" 200th " . . .	−0·042
	Ditto . .	" 207¼th " or end of line .	−0·075
No. 2 Detachment.	Line Mymensingh-Dacca .	" 10th " . . .	+0·002
	Ditto . .	" 30th " . . .	+0·011
	Ditto . .	" 60th " . . .	+0·068
	Ditto . .	" 87th " or end of line .	+0·085
	Revision of Pāchuriā-Porādaha.	" 10th " . . .	+0·029
	Ditto . .	" 21st " . . .	+0·018
	Ditto . .	" 30th " . . .	+0·001
	Ditto . .	" 47th " or end of line .	+0·025
	Line Howrah-Benares .	" 5th " . . .	−0·010
	Ditto . .	" 10th " . .	−0·029
	Ditto . .	" 20th " . . .	−0·029
	Ditto . .	" 23rd " or end of line .	−0·035
	Line Tindhāria-Darjeeling	" 10th " . . .	−0·019
	Ditto . .	" 20th " . . .	−0·097
	Ditto . .	" 30th " . . .	−0·176
	Ditto . .	" 33rd " or end of line .	−0·168
No. 3 Detachment.	Line Taunggyi-Thazi .	" 25th " . . .	−0·081
	Ditto . .	" 52nd " . . .	+0·021
	Ditto . .	" 76th " . . .	+0·140
	Ditto . .	" 94th " or end of line .	+0·070
	Line Magwe-Taungdwingyi	" 22nd " . . .	+0·111
	Ditto . .	" 52nd " . . .	+0·109
	Ditto . .	" 63rd " or end of line .	+0·125
	Line Mokpalin-Amherst .	" 26th " . . .	+0·062
	Ditto . .	" 56th " . . .	+0·126
	Ditto . .	" 75th " . . .	+0·147
	Ditto . .	" 100th " . . .	+0·083
	Ditto . .	" 124th " . . .	+0·041
	Ditto . .	" 153rd " or end of line .	+0·046

MAGNETIC SURVEY.

No. 18 PARTY.

(*Vide* Index Map 11.)

BY CAPTAIN R. H. THOMAS, R. E.

PERSONNEL.

Imperial Officers.

Captain R. H. Thomas, R. E.
Lieutenant K. Mason, R.E., from 1st May 1914.

Provincial Officers.

Mr. H. P. D. Morton.
" R. P. Ray, B.A.
" N. R. Mazumdar.
" R. B. Mathur, B.A.

Upper Subordinate Service.

Mr. B. B. Shome.

Lower Subordinate Service.

4 Magnetic Observers, 14 Computers, etc.

The present report on the work of the magnetic party in 1913-14 comprises:—

I.—An account of the work in the field and recess quarters.

II.—A note on the Observatories during 1913-14.

III.—Tables of results including:—

(*a*) Preliminary values of the magnetic elements at field and repeat stations.

(*b*) Diurnal variation and inequality of the magnetic elements at each of the four survey base stations.

Appendix.—Report of the Committee appointed by the Government of India to discuss the present state of the Magnetic Survey. (Printed under Part III—Special Reports).

I.—FIELD OPERATIONS AND RECESS WORK IN 1913-14.

1. *Field operations.*—The field season opened on October 24th 1913 and closed at the end of April 1914.

In view of the desirability of accelerating the reduction of the survey and the publication of results, field work was confined to the comparison of instruments at observatories and observations at repeat stations. Two detachments were employed for this purpose, one under the officer in charge for about two months, the second under Mr. H. P. D. Morton for the whole field season. Comparative observations were made at the four survey base stations and at Alibāg while 61 repeat stations were reoccupied.

Of the three remaining Provincial Officers, Mr. Mazumdar remained at the camp head-quarters at Dehra Dūn in charge of the computing section, and it was intended to retain Messrs. R. P. Ray and R. B. Mathur at head-quarters throughout the field season for the work of reduction.

Special detailed survey round Poona.

In December 1913, however, orders were received to carry out detailed magnetic surveys in the districts of Poona, Nāsik and Ahmadnagar in connection with the proposed erection of one of the stations of the Imperial wireless chain. Mr. Ray and a detachment took the field in December for this purpose, but after observing at 30 stations in the Poona District, instructions were received to discontinue the work as the investigation was no longer considered necessary; the detachment was therefore withdrawn and returned to Dehra Dūn on 20th February 1914.

The chief points upon which information was sought were

(*a*) Are there any ranges of magnetic hills on the lines between Cairo and Poona and between Poona and Singapore within a distance of about 50 miles from Poona (the Cairo-Singapore line being reckoned as several miles wide)?

(*b*) Are there in Poona or on the Cairo-Poona-Singapore line within 50 miles of Poona any points of strong magnetic disturbance and if so what are the magnetic deflections?

Observations were made about 5 miles apart along a belt about 5 miles wide; in the vicinity of hills crossing the Cairo-Poona-Singapore line stations were sited on opposite sides of and as close to the hills as was found practicable, while the observer was instructed to carefully test the magnetic properties of

the stones in the vicinity of each station, specimens being labelled and transmitted to Dehra Dūn.

The surface rock over the whole of the area magnetically surveyed is Deccan trap, which previous experience had shown to be highly magnetic; stones selected at random in the vicinity of a station almost invariably deflect the needle, while pieces of rock with well defined poles are not infrequently found. Local disturbances under such circumstances are inevitable; a considerable number of stations however in the Deccan trap area have been re-observed; in most of these cases the identification of the station was dependent on the descriptions furnished by the previous observer and errors of location were therefore in some cases likely to amount to 30 or 40 feet; but these "repeat" observations have served to show that these local disturbances while at times of considerable magnitude, are usually of very restricted range. No great weight, therefore, attaches to abnormal observations if these are confined to a single station of observation; the observations at 3 of the 30 stations observed around Poona were rejected for this reason.

The remaining 27 stations were reduced to January 1st 1914 and the disturbances calculated by the usual method.

The following conclusions were drawn :—

(*a*) There are two regions of magnetic attraction to the north-west and south-east of Poona respectively, the "valley" line dividing them passing west of Poona: the centres of attraction are weak as their effect only extends over a limited area.

(*b*) The magnetic disturbances are unconnected with the superficial topography.

2. *Work during recess.*—In March 1914 a Committee was appointed by the Government of India to consider the present position of the magnetic survey and to advise on the measures necessary to complete it; the committee sat for about a fortnight and submitted a report which is published in this volume as an appendix.

Committee on the present position of the magnetic survey.

During the recess, the computation of the field work and the reduction and tabulation of the results from the base stations for 1913 have been completed; the tables of diurnal variation and inequality are based on the measurements of "all days" excluding only those of great disturbance.

Reduction of the survey.

Good progress has been made with the reduction; the declination data have been practically completed; in horizontal force the measurements of the base station magnetograms at times corresponding to the field observations are in hand. Of the latter the measurements for the repeat stations were first taken up in order to determine the secular change in different districts and are nearly completed; it remains to apply the revised base line values of the magnetographs which will result from the investigation of the instrumental differences in H. F. referred to in previous reports.

Health of party.—The health of the party was satisfactory—the recorder at Barrackpore Observatory resigned his appointment owing to ill-health after onl six and half months, service.

3. *Programme for 1914-15.*—During the ensuing field season field work will be limited to comparisons of instruments at the observatories and to observations at repeat stations; in accordance with the recommendations of the Committees on the magnetic survey the repeat stations will be marked in such a manner a is most likely to ensure their permanency and handed over to the care of the local authorities. In ensuing years, the only field work required will be the comparison of instruments at the Dehra Dūn, Toungoo, Kodaikānal and Alibāg observatories; Barrackpore observatory in the opinion of the Committee may be closed.

4. *Results published with this report.*—Tables showing the approximate values (uncorrected) of the magnetic elements at the field and repeat stations in 1913-14 are appended, with an index chart showing the progress of the survey.

The tabulations of the results at the four survey base stations are published for 1913.

II.—THE OBSERVATORIES IN 1913-14.

A.—DEHRA DŪN OBSERVATORY.

1. Magnetic observer Babu Sri Dhar held charge of the observatory during the first half of the year, and the latter part of December. Mr. R. P. Ray held charge for the remainder of the year in addition to his own duties.

The H. F. and declination magnetographs have worked satisfactorily during the year; an improvement in the V. F. instrument was effected by the replacement of the former agate plane by one allowing a little more clearance to the magnet.

2. *Mean values of constants.*—The table below gives the mean monthly values of magnetic collimation, the coefficients $P_{1\text{-}2}$, $P_{2\text{-}3}$ derived from observations at the three distances 22·5, 30 and 40 cms. and the observed and accepted values of the magnetic moment used in the computations for 1913.

There was a considerable fall in the magnetic moment of the standard magnet No. 17 about the 28th April 1913, the values of magnetic collimation and $P_{1\text{-}2}$ and $P_{2\text{-}3}$ being also affected; the observer in charge can give no explanation of this fall of moment which can only have resulted from the magnet being dropped or otherwise violently jarred.

Mean values of the constants of the Magnetometer No. 17 in 1913.

MONTHS.	DECLINATION CONSTANTS.	H. F. CONSTANTS.						Accepted m_o.	REMARKS.
		MEAN VALUES OF P'S.				MEAN VALUES OF m_o.			
	Mean magnetic collimation.	$P_{1\text{-}2}$	$P_{2\text{-}3}$	Accepted value of $P_{1\text{-}2}$	Accepted value of $P_{2\text{-}3}$	By eye and ear.	By Chronograph.		
	′ ″								
January . . .	−9 : 25	7·31	8·01						
February . .	9 : 27	7·30	8·24	7·17*a*		892·99	893·32*a*	893·23*a*	(*a*) to April 26th.
March . . .	9 : 23	7·26	8·05						
April . . .	9 : 18*a* 5 : 48	7·28	7·89				813·41*	813·41*	* For 28th April only.
May . . .	5 : 43	6·18	6·56			812·43	812·62	812·62	
June . . .	5 : 43	6·12	6·93						
July . . .	5 : 53	6·01	6·77						
August . . .	5 : 57	6·07	6·63	6·02*b*					
September . .	5 : 57	5·95	6·54			812·05	812·08	812·08	(*b*) From April to 28th end.
October . . .	5 : 57	5·86	6·64						
November . .	5 : 58	6·06	6·27						
December . .	5 : 58	6·06	6·60						

3. *Mean base line values.*—The table below gives the monthly mean values of the Declination and H. F. base lines, they have been used to obtain the values of H. F., etc., in the tables attached to this report.

The decrease in the value of the base line for May is coincident with the large decrease in the value of the magnetic moment previously referred to; this decrease is however confirmed by observations taken with another magnetometer during April and May.

Base line values of Magnetographs in 1913.

MONTHS.	DECLINATION. Mean value of Base line.	DECLINATION. Base line accepted.	DECLINATION. REMARKS.	HORIZONTAL FORCE. Mean value of Base line.	HORIZONTAL FORCE. Base line accepted.	HORIZONTAL FORCE. REMARKS.
January . . .	1°:30′·6	1° : 30′·6 throughout.		·32916	·32916	
February . . .	1 : 30·3			·32913	·32913	
March . . .	1 : 30·5			·32908	·32909	
April . . .	1 : 30·9			·32910	·32909	
May . . .	1 : 30·7			·32892	·32904	
June . . .	1 : 30·7			·32889	·32899	
					·32894	To 10 h. on 29th.
July . . .	1 : 30·8			·32894	·32890	From 11 h. on 29th to 10 h. on 31st.
					·32886	From 11 h. on 31st.
					·32886	To 10 h. on 13th.
August . . .	1 : 30·6			·32882	·32880	From 11 h. on 13th.
September . .	1 : 30·5			·32882	·32880	
					·32880	To 10 h. on 19th.
October . . .	1 : 30·5			·32875	·32876	From 11 h. on 19th to 20th.
					·32873	21st—22nd.
					·32870	From 23rd.
November . .	1 : 30·4			·32867	·32870	To 13th November.
					·33868	14th and 15th.
					·32865	From 16th November.
December . .	1 : 30·5			·32865	·32865	

4. *The mean scale values for 1913* for an ordinate of $\frac{1}{25}$ inch were as follows :—

H. F. 4·47γ

D. 1′·03

V. F. 3·87γ to 5·93γ.

The maximum and minimum monthly temperatures of the H. F. and V. F. magnetographs were 27°·0 and 26°·9 C respectively.

5. *Mean monthly values and secular change 1912-13.*—The following table shows the monthly mean values of the magnetic elements in 1912–13 and the secular change during that period.

Secular changes at Dehra Dūn in 1912-13.

MONTHS.	HORIZONTAL FORCE ·33000 C. G. S. +			DECLINATION E. 2° +			DIP N. 44° +			VERTICAL FORCE ·32000 C. G. S. +		
	1912.	1913.	Secular change.	1912.	1913.	Secular change.	1912.	1913.	Secular change.	1912.	1913.	Secular change.
	γ	γ	γ	′	′	′	′	′	′	γ	γ	γ
January . .	225	199	—26	27·2	24·0	—3·2	5·8	12·8	+7·0	194	299	+105
February . .	226	201	—25	26·9	23·8	—3·1	6·2	14·2	+8·0	201	328	+127
March . .	224	199	—25	26·8	23·3	—3·5	7·0	14·8	+7·8	214	337	+123
April . . .	219	194	—25	26·6	22·9	—3·7	7·3	15·6	+8·3	216	348	+132
May . . .	218	197	—21	26·4	22·6	—3·8	7·9	16·1	+8·2	225	359	+134
June . . .	224	199	—25	25·6	22·3	—3·3	7·9	16·2	+8·3	232	364	+132
July . . .	223	196	—27	25·7	22·1	—3·6	8·8	16·6	+7·8	248	367	+119
August . .	211	189	—22	25·4	21·8	—3·6	9·7	17·2	+7·5	253	372	+119
September . .	211	180	—31	25·3	21·4	—3·9	10·7	17·8	+7·1	272	375	+103
October . .	208	177	—31	25·1	21·0	—4·1	11·4	18·4	+7·0	282	384	+102
November . .	204	179	—25	25·3	20·8	—4·5	12·1	18·3	+6·2	291	383	+92
December . .	201	180	—21	24·4	20·4	—4·0	12·6	18·8	+6·2	297	394	+97
Means . .	216	191	—25	25·9	22·2	—3·7	9·0	16·4	+7·4	244	359	+115

NOTE.—The values given herein have been deduced from all available days.

B.—BARRACKPORE OBSERVATORY.

1. Magnetic observer Babu K. N. Mukerji was in charge of the observatory during the year except during October and November 1913 when he was on sick leave and was replaced by Babu Sri Dhar from Dehra Dūn.

The observatory was, as usual, extremely unhealthy during the rainy season; recorder B. B. Bhattacharji was obliged to resign his appointment owing to ill-health after only 6½ months' service.

None of the magnetographs required adjustment during the year.

2. *Mean values of constants.*—The table below shows the monthly mean values of magnetic collimation, the distribution coefficients and the magnetic moment (m_0) of the observatory magnetometer in 1913.

Mean values of the constants of the Magnetometer No. 20 in 1913.

Months.	Declination Constants.	H. F. Constants.					Remarks.
	Mean magnetic collimation.	Mean values of P's.			Mean values of m_0	Accepted m_0	
		$P_{1\cdot2}$	$P_{2\cdot3}$	Accepted value of $P_{1\cdot2}$			
	′ ″						
January	—7 : 51	6·94	7·39				For a great portion of the year, the deflection observations are of doubtful value: the monthly values of the base line and H. F. have been derived from the vibration observations.
February	—7 : 58	7·00	7·46				
March	—7 : 47	6·97	7·47				
April	—7 : 50	7·04	7·19				
May	—7 : 52	7·17	7·20				
June	—7 : 53	7·15	7·36				
July	—7 : 53	7·12	7·11				
August	—7 : 50	7·08	7·20				
September	—7 : 35	6·99	...	6·82 (a) (September to December)			
October	—7 : 32	6·95	7·28		937·33 (b)	937·80 (e)	
November	—7 : 33	6·88	7·13		936·64 (c)	937·11 (f) (November and December)	(a) From 23rd Sept. to end. (b) „ 4th to 18th Octr. (c) „ 21st Octr. to 9th Decr.
December	—7 : 29	6·86	7·16		937·11 (d)		(d) „ 4th, 8th and 9th to 31st Decr. (e) From 23rd Sept. to 18th Octr. (f) From 21st Octr. to end.

3. *Mean values of Base Lines.*—The following table gives the mean monthly observed values of the base lines in the H. F. and Declination instruments and those actually used in the computations.

Base line values of the Magnetographs in 1913.

Months.	Declination.			Horizontal Force.		
	Mean value of Base line.	Accepted Base line.	Remarks.	Mean value of Base line.	Accepted Base line.	Remarks.
	° ′					
January	—0 : 4·2	—0° : 4′·1 throughout		·37087	·37084	
February	—0 : 4·2			·37078	·37084	
March	—0 : 4·0			·37083	·37084	
April	—0 : 4·0			·37088	·37084	
May	—0 : 4·0			·37088	·37084 ·37087	To 20th May. To 30th May.
June	—0 : 4·1			·37094	·37091 ·37094	To 10th June. To 20th June.
July	—0 : 4·0			·37101	·37097 ·37100 ·37104	To 10th July. To 20th July. To 31st July.

Base line values of the Magnetographs in 1913—concld.

MONTHS.	DECLINATION.			HORIZONTAL FORCE.		
	Mean value of Base line.	Accepted Base line.	REMARKS.	Mean values of Base line.	Accepted Base line.	REMARKS.
	° ′					
August	0 : 4·0	—0° : 4′·1 throughout		·37109	·37108	
September	0 : 4·2			·37106	·37108	
October	0 : 4·0			·37103	·37108	To 20th October.
					·37105	To 31st October.
November	0 : 3·9			·37097	·37101	To 10th November.
					·37098	From 11th November.
December	0 : 3·8			·37098	·37098	

4. ***Mean scale values and temperature range.***—The mean scale values for the year for an ordinate of $\frac{1}{25}$ inch were as follows:—

H. F.	4·86γ
Decln.	1′·03
V. F.	4·62γ

The maximum and minimum monthly values of the temperature of the H. F. and V. F. instruments were 32°·3 and 30°·4 C; the temperature of reduction is 31° C.

5. ***Mean monthly values and secular changes.***—The table below shows the mean monthly values of the magnetic elements for 1912-13 and the secular changes during that period.

Secular changes at Barrackpore in 1912-13.

MONTHS.	HORIZONTAL FORCE ·37000 C. G. S. +			DECLINATION E. 0° +			DIP. N. 30° +			VERTICAL FORCE ·22000 C. G. S. +		
	1912.	1913.	Secular change.	1912.	1913.	Secular change.	1912.	1913.	Secular change.	1912.	1913.	Secular change.
	γ	γ	γ	′	′	′	′	′	′	γ	γ	γ
January	356	384	+ 28	46·8	40·6	—6·2	48·8	52·9	+4·1	280	357	+ 77
February	361	387	+ 26	46·3	40·3	—6·0	49·2	53·3	+4·1	289	365	+ 76
March	362	388	+ 26	45·8	39·8	—6·0	49·3	53·5	+4·2	291	368	+ 77
April	364	376	+ 12	45·1	39·3	—5·8	50·1	54·1	+4·0	305	371	+ 66
May	372	380	+ 8	44·6	38·	—5·8	50·4	54·3	+3·9	313	375	+ 62
June	373	389	+ 16	44·2	38·3	—5·9	50·6	54·5	+3·9	318	384	+ 66
July	376	389	+ 13	43·7	37·7	—6·0	50·9	55·0	+4·1	324	391	+ 67
August	369	396	+ 27	43·3	37·2	—6·1	51·3	55·1	+3·8	325	398	+ 73
September	370	388	+ 18	42·7	36·8	—5·9	51·8	55·7	+3·9	332	401	+ 69
October	372	389	+ 17	42·2	36·2	—6·0	51·8	56·0	+4·2	334	406	+ 72
November	367	395	+ 28	41·8	35·9	—5·9	52·4	56·0	+3·6	340	410	+ 70
December	373	399	+ 26	41·2	35·5	—5·7	52·5	56·7	+4·2	345	422	+ 77
Means	368	388	+ 20	44·0	38·0	—6·0	50·8	54·8	+4·0	316	387	+ 71

NOTE.—The values given herein have been deduced from all available days.

C.—TOUNGOO OBSERVATORY.

1. Magnetic observer Babu K. K. Dutta held charge of the observatory until January 8th, 1914, when he was relieved by Mr. B. B. Shome, Upper Subordinate Service, who was in charge for the remainder of the year.

The magnetographs have worked satisfactorily throughout the year; the declination instrument was readjusted and the torsion head of the H. F. instrument turned on 25th December 1913 on account of the gradual shift of the trace due to secular change.

2. *Mean values of constants.*—The table below gives the mean monthly observed values of magnetic collimation, the distribution constants and the magnetic moment during 1913: the change in magnetic collimation in November is coincident with a fall in magnetic moment. The normal fall in the moment of the observatory magnet (No. 19 A) shows no signs of diminution; it amounts to about 2·0 c. g. s. per annum or about ten times as great as the average normal fall of the other survey magnets by the same maker, which seems to show the magnet was not properly annealed during manufacture.

Mean values of the constants of the Magnetometer No. 19 in 1913.

MONTHS.	DECLINATION CONSTANTS.	H. F. CONSTANTS.					REMARKS.
	Mean magnetic collimation.	MEAN VALUES OF P's.			Mean value of m_o.	Accepted m_o.	
		$P_{1\cdot2}$	$P_{2\cdot3}$	Accepted $P_{1\cdot2}$			
	′ ″						
January	—9 : 22	8·35	9·13	8·41 throughout.		884·03	
February	—9 : 7	8·14	8·94			883·78	
March	—9 : 4	8·14	8·98			883·72	
April	—9 : 7	8·14	8·98			883·56	April 4th to May 21st.
May	—9 : 1	8·19	8·64			883·00	May 22nd to May 29th.
June	—9 : 15	8·28	8·83			882·71	For June 7th only.
July	—9 : 11	8·23	9·13			882·23	
August	—9 : 20	8·27	8·84			882·11	Augt. 2nd to Sept. 18th.
September	—9 : 21	8·29	8·79			881·70	Sept. 20th to Nov. 12th.
October	—9 : 24	8·36	8·31				
November	—9 : 53	8·28	8·36			879·50	For 17th Nov.
December	—9 : 54	8·37	8·31			879·13	Nov. 18th to Dec. 29th.

3. *Mean base line values.*—The following table gives the mean monthly observed and accepted values of the base lines of the H. F. and Declination magnetographs: the accepted values are those used in the computations.

The observed base lines require a correction of—19γ to reduce them to magnet 19 which was in use up to 1907: the remaining differences between the observed and accepted base lines are due to "personal error," the latter values being based on comparisons with No. 10 instrument in December 1912 and December 1913.

Base line values of magnetographs in 1913.

MONTHS.	DECLINATION.			HORIZONTAL FORCE.		
	Mean value of Base line.	Accepted Base line.	REMARKS.	Mean value of Base line.	Accepted Base line.	REMARKS.
	° ′	° ′				
January	0 : 31·5	0 : 31·6 (January to August)		·38472	·38436	
February	0 : 31·8			·38477	·38441	
March	0 : 31·7			·38477	·38445	
April	0 : 31·5			·38483	·38450	
May	0 : 31·6			·38484	·38454	
June	0 : 31·2			·38459	·38459	
July	0 : 31·5			·38444	·38463	
August	0 : 31·7			·38443	·38464	
September	0 : 31·2	0 : 31·1 (September to December)	Up to 9 h. on 25th Decr.	·38444	·38463	
October	0 : 31·2			·38442	·38461	
November	0 : 31·0			·38442	·38461	
December	0 : 30·9			·38437	·38456	To 9 h. on 25th.
	0 : 50·4	0 : 50·4	From 10 h. on 25th Decr.	·38649	·38668	From 10 h. on 25th.

4. ***Mean scale values and temperature range.***—The mean scale values for the year 1913 for an ordinate of $\frac{1}{25}$ inch are :—

H. F.	5·49γ
Declination	1′·04.
V. F.	5·61γ.

The maximum and minimum temperatures of the magnetographs during 1913 were 89°·7 and 89°·1 F. : the temperature of reduction is 89° F.

5. ***Monthly mean values and secular changes.***—The annexed table shows the mean monthly values of the magnetic elements for 1912-13 and the secular changes during that period.

Secular changes at Toungoo in 1912-13.

MONTHS.	HORIZONTAL FORCE, ·38000 C. G. S.+			DECLINATION, E. 0°+.			DIP, N. 23°+.			VERTICAL FORCE, ·16000 C. G. S.+		
	1912.	1913.	Secular change.	1912.	1913.	Secular change.	1912.	1913.	Secular change.	1912.	1913.	Secular change.
	γ	γ	γ	′	′	′	′	′	′	γ	γ	γ
January	866	920	+54	16·1	10·1	−6·0	2·5	5·1	+2·6	531	588	+57
February	872	930	+58	15·6	9·7	−5·9	2·9	4·4	+1·5	539	584	+45
March	877	939	+62	15·1	9·2	−5·9	2·8	4·5	+1·7	539	589	+50
April	874	940	+66	14·5	8·7	−5·8	2·8	4·8	+2·0	538	594	+56
May	880	955	+75	14·1	8·2	−5·9	2·8	5·0	+2·2	541	602	+61
June	892	969	+77	13·9	8·0	−5·9	2·7	5·0	+2·3	545	609	+64
July	898	979	+81	13·3	7·5	−5·8	3·2	4·9	+1·7	553	611	+58
August	891	983	+92	12·7	6·9	−5·8	2·6	5·1	+2·5	543	616	+73
September	894	979	+85	12·1	6·9	−5·2	2·6	5·0	+2·4	544	613	+69
October	901	979	+78	11·7	6·4	−5·3	2·7	5·4	+2·7	549	617	+68
November	900	991	+91	11·3	5·9	−5·4	4·2	5·3	+1·1	568	622	+54
December	905	994	+89	10·7	5·7	−5·0	5·1	5·1	0·0	583	620	+37
Means	888	963	+75	13·4	7·8	−5·6	3·1	5·0	+1·9	548	605	+57

NOTE.—The values given herein have been deduced from all available days.

D.—KODAIKĀNAL OBSERVATORY.

The observatory was in charge of Magnetic Observer Ramasvami Ayyangar until 17th August 1914 when he proceeded on 3 months' leave, Computer Abdul Majid officiating.

The magnetographs have given no trouble; the only adjustment required being in the H. F. instrument in which the torsion head was turned in April 1914 on account of the shift of the trace due to secular change.

Since March 1913 all vibration observations have been taken by chronograph; the improvement in the observations as compared to the eye and ear method is most marked.

The Director and Acting Director, Solar Physics Observatory, have in this, as in former years, given the most cordial assistance in the magnetic work.

2. *Mean values of constants.*—The following table gives the mean values of the constants of magnetometer No. 16: the agreement between the mean monthly values of m_o by chronograph, will be seen to be remarkably good.

Mean values of the constants of the Magnetometer No. 16 in 1913.

MONTHS.	DECLINATION CONSTANTS.	H. F. CONSTANTS.						REMARKS.
	Mean magnetic collimation.	MEAN VALUES OF P's.			MEAN VALUE OF m_o.			
		$P_{1\text{-}2}$	$P_{2\text{-}3}$	Accepted value of $P_{1\text{-}2}$.	By eye and ear.	By Chronograph.	Accepted m_o.	
	′ ″							
January	—3 : 29	6·52	8·46	6·56	885·59 (January–February)	886·67	886·69 (January–March)	
February	—3 : 28	6·43	8·37	6·43		·68		
March	—3 : 27	6·29	8·45	6·29 (March–December)		·70		
April	—3 : 27	6·36	8·26			·56	886·57 (April–August)	
May	—3 : 24	6·32	8·09			·56		
June	—3 : 22	6·30	8·30			·56		
July	—3 : 27	6·27	8·34			·58		
August	—3 : 26	6·26	8·44			·58		
September	—3 : 27	6·16	8·52			·35	886·39 (September–December)	
October	—3 : 24	6·33	8·32			·42		
November	—3 : 28	6·18	8·22			·39		
December	—3 : 27	6·30	8·19			·45		

3. *Mean monthly base line values.*—The table below gives the mean monthly observed and accepted values of the base lines of the H. F. and Declination magnetographs; the accepted values are those actually used in the computations.

Base line values of magnetographs in 1913.

MONTHS.	DECLINATION.			HORIZONTAL FORCE.		
	Mean value of Base line.	Accepted Base line.	REMARKS.	Mean value of Base line.	Accepted Base line.	REMARKS.
	° ′					
January	1 : 58·4	1° : 58′·4 throughout.		·37184	·37184	
February	1 : 58·5			·37178	·37178	
March	1 : 58·4			·37174	·37174	
April	1 · 58·6			·37174	·37174	

Base line values of magnetographs in 1913—concld.

MONTHS.	DECLINATION.			HORIZONTAL FORCE.		
	Mean value of Base line.	Accepted Base line.	REMARKS.	Mean value of Base line.	Accepted Base line.	REMARKS.
	° ′					
May . . .	1 : 58·4	1° : 58′·4 throughout.		·37172	·37172	
June . .	1 : 58·4			·37172	·37172	
July . . .	1 : 58·5			·37167	·37169	
August . . .	1 : 58·3			·37167	·37167	
September . .	1 : 58·4			·37166	·37167	
October . . .	1 : 58·2			·37168	·37165	
November . .	1 : 58·3			·37164	·37162	
December . .	1 : 58·4			·37158	·37158	

4. *Mean scale values and temperature range.*—The mean scale values for the year for an ordinate of $\frac{1}{25}$ inch are as follows:—

H. F.	6·01γ
V. F.	4·91γ
Declination	1′·03.

The maximum and minimum monthly mean temperatures of the magnetographs were 18°·2 and 17°·5 C. respectively.

5. *Mean monthly values and secular changes.*—The annexed table gives the mean monthly values of the magnetic elements in 1912 and 1913 and the secular changes during that period.

Secular changes at Kodaikānal in 1912-13.

MONTHS.	HORIZONTAL FORCE ·37000 C. G. S. +			DECLINATION W. 1° +			DIP N 3° +			VERTICAL FORCE ·02000 C. G. S. +		
	1912.	1913.	Secular change.	1912.	1913.	Secular change.	1912.	1913.	Secular change.	1912.	1913.	Secular change.
	γ	γ	γ	′	′	′	′	′	′	γ	γ	γ
January . . .	534	554	+20	3·3	8·7	+5·4	56·1	62·2	+6·1	582	650	+68
February . . .	538	548	+10	3·8	9·2	+5·4	56·8	62·5	+5·7	598	653	+64
March	532	547	+15	4·4	9·7	+5·3	57·0	63·3	+6·3	592	662	+70
April	528	546	+18	4·6	10·0	+5·4	57·8	64·2	+6·4	599	672	+73
May	531	549	+18	5·2	10·6	+5·4	58·5	64·8	+6·3	607	678	+71
June	537	554	+17	5·6	11·0	+5·4	59·3	65·7	+6·4	617	688	+71
July . . .	542	553	+11	6·0	11·4	+5·4	59·8	66·1	+6·3	623	692	+69
August . . .	543	558	+15	6·4	11·9	+5·5	59·9	66·5	+6·6	624	698	+74
September . . .	549	557	+ 8	6·9	12·4	+5·5	60·1	66·8	+6·7	627	701	+74
October . . .	555	556	+ 1	7·4	12·9	+5·5	60·6	67·6	+7·0	633	710	+77
November . . .	552	560	+ 8	7·8	13·3	+5·5	61·4	67·7	+6·3	641	710	+69
December . . .	558	558	0	8·4	13·8	+5·4	62·0	68·0	+6·0	648	714	+66
Means	542	553	+11	5·8	11·2	+5·4	59·1	65·5	+6·4	615	686	+71

NOTE.—The values given herein have been deduced from all available days.

III.—TABLES OF RESULTS.

A.—Mean values of the magnetic elements at observatories in 1913.

Observatory.	Latitude and Longitude.	Dip.	Declination.	H. F.	V. F.
	° ′ ″	° ′	° ′	C. G. S.	C. G. S.
Dehra Dūn .	30 : 19 : 19 N 78 : 3 : 19 E	N. 44 : 16·4	E. 2 : 22·2	·33191	·32359
Barrackpore .	22 : 46 : 29 N 88 : 21 : 39 E	N. 30 : 54·8	E. 0 : 38·0	·37388	·22387
Toungoo . .	18 : 55 : 45 N 96 : 27 : 3 E	N. 23 : 5·0	E. 0 : 7·8	·38963	·16605
Kodaikānal .	10 : 13 : 50 N 77 : 27 : 46 E	N. 4 : 4·5	W. 1 : 11·2	·37553	·02686

B.—Dates of Magnetic disturbances, 1913.

D=Dehra Dūn . { Lat. 30° 19′ 19″; Long. 78° 3′ 19″

B=Barrackpore . { Lat. 22° 46′ 29″; Long. 88° 21′ 39″

T=Toungoo . { Lat. 18° 55′ 45″; Long. 96° 27′ 3″

K=Kodaikanal . { Lat. 10° 13′ 50″; Long. 77° 27′ 46″

Date.	January.				February.				March.			
1913	D	B	T	K	D	B	T	K	D	B	T	K
1	(C)	(C)	(C)	(C)	S	S	C	C	C	C	C	C
2	S	S	S	S	S	C	C	C	C	C	C	C
3	M	M	M	M	C	C	C	C	C	C	C	C
4	S	S	S	C	(C)	(C)	(C)	(C)	C	C	C	S
5	S	S	S	S	(C)	(C)	(C)	(C)	C	C	C	C
6	(C)	(C)	(C)	(C)	C	C	C	C	C	C	C	C
7	C	C	C	C	S	S	S	S	S	S	S	S
8	S	C	C	C	S	S	S	S	S	S	S	S
9	S	S	S	S	S	S	S	S	S	S	S	S
10	S	S	S	S	C	C	C	S	(C)	(C)	(C)	(C)
11	C	C	C	C	C	C	C	C	S	S	S	S
12	(C)	(C)	(C)	(C)	S	S	S	S	S	S	S	S
13	C	C	C	C	S	S	S	S	—	S	S	C
14	S	S	S	S	M	M	M	M	—	M	M	M
15	S	S	S	C	S	S	S	S	S	S	S	S
16	(C)	(C)	(C)	(C)	S	S	S	S	S	S	S	S
17	C	C	C	C	—	S	S	S	S	S	S	S
18	S	S	S	S	—	S	S	S	—	S	S	C
19	M	M	M	S	—	S	S	S	—	C	C	C
20	S	S	S	C	C	C	C	C	(C)	(C)	(C)	(C)
21	S	S	S	S	S	S	S	S	S	S	S	S
22	S	C	C	C	(C)	(C)	(C)	(C)	S	C	C	C
23	C	C	C	C	(C)	(C)	(C)	(C)	S	S	S	S
24	C	C	C	C	(C)	(C)	(C)	(C)	S	S	S	S
25	S	S	S	S	M	S	S	S	(S)	(C)	(C)	(C)
26	(S)	(S)	(S)	(C)	M	M	M	M	C	C	C	C
27	S	S	S	S	S	S	S	S	(C)	(C)	(C)	(C)
28	S	S	S	S	C	C	C	C	—	C	C	S
29	S	S	S	S	...	...	...	...	—	S	S	C
30	M	M	M	M	...	...	...	...	S	S	S	S
31	S	S	S	S	...	...	...	...	S	S	S	S
C	10	12	12	16	11	12	13	12	10	14	14	15
S	18	16	16	13	11	14	13	14	15	16	16	15
M	3	3	3	2	3	2	2	2	...	1	1	1
G	...	...	...	...	...	...	...	...	...	...	...	...
V. G.	...	...	...	...	...	...	...	...	...	...	...	...
Trace lost	...	...	...	...	3	...	...	...	6	...	...	...

Date.	April.				May.				June.			
1913	D	B	T	K	D	B	T	K	D	B	T	K
1	S	S	S	S	S	S	S	S	S	S	S	S
2	S	C	C	C	S	S	S	S	S	S	S	S
3	S	S	S	S	S	S	S	S	S	S	S	S
4	S	S	S	S	M	M	M	M	S	S	S	S
5	(C)	(C)	(C)	(C)	M	M	M	M	C	C	C	C
6	(C)	(C)	(C)	(C)	M	M	M	M	C	C	C	C
7	S	S	S	S	S	S	S	S	C	C	C	C
8	(C)	(C)	(C)	(C)	S	S	S	S	(C)	(C)	(C)	(C)
9	G	G	G	G	S	C	C	C	C	C	C	C
10	M	M	M	M	C	C	C	C	C	C	C	C
11	S	S	S	S	C	C	C	C	(C)	(C)	(C)	(C)
12	S	S	S	S	(C)	(C)	(C)	(C)	(C)	(C)	(C)	(C)
13	M	M	M	S	C	C	C	C	C	C	C	C
14	S	S	S	S	(C)	(C)	(C)	(C)	S	S	S	S
15	S	S	S	S	C	C	C	C	S	S	S	S
16	S	S	S	S	C	C	C	C	S	S	S	S
17	S	S	S	S	C	C	C	C	S	C	C	C
18	C	C	C	C	S	S	S	S	(C)	(C)	(C)	(C)
19	C	C	C	C	S	S	S	S	S	S	S	C
20	(C)	(C)	(C)	(C)	(C)	(C)	(C)	(C)	S	S	S	S
21	C	C	C	C	(C)	(C)	(C)	(C)	S	C	S	C
22	C	C	C	C	C	C	C	C	S	S	S	C
23	S	C	S	S	(C)	(C)	(C)	(C)	S	S	S	C
24	C	C	C	C	C	C	C	C	S	S	S	S
25	(C)	(C)	(C)	(C)	C	C	C	C	C	C	C	C
26	C	C	C	C	C	C	C	C	S	S	S	S
27	S	S	S	S	S	S	S	C	(C)	(C)	(C)	(C)
28	S	S	S	S	S	S	C	C	S	S	S	S
29	C	C	C	C	S	S	S	C	S	S	S	S
30	C	C	C	C	S	S	S	S	S	S	S	S
31	...	...	...	...	C	C	C	C	...	...	...	...
C	13	15	14	14	16	17	18	20	12	13	14	17
S	14	12	13	14	12	11	10	8	18	16	16	13
M	2	2	2	1	3	3	3	3	...	...	...	...
G	1	1	1	1	...	...	...	...	...	...	...	...
V. G.	...	...	...	...	...	...	...	...	...	...	...	...
Trace lost	...	...	...	...	...	...	...	...	...	...	...	...

Date.	July.				August.				September.			
1913	D	B	T	K	D	B	T	K	D	B	T	K
1	S	S	S	S	C	C	C	C	S	S	S	S
2	S	S	S	C	(C)	(C)	(C)	(C)	C	C	C	C
3	C	C	C	C	S	S	S	S	S	S	S	S
4	(C)	(C)	(C)	(C)	S	S	S	S	(C)	(C)	(C)	(C)
5	C	C	C	C	(S)	(S)	(S)	(C)	C	C	C	C
6	C	C	C	C	S	S	S	S	S	S	S	S
7	S	S	S	S	S	S	S	S	S	S	S	S
8	S	S	S	C	C	C	C	C	M	M	M	S
9	(C)	(C)	(C)	(C)	S	S	S	S	M	S	S	S
10	S	S	S	C	S	S	S	S	S	S	S	S
11	S	S	S	C	S	S	S	S	S	S	S	S
12	M	M	M	S	S	S	S	S	S	S	S	S
13	S	S	S	S	S	S	S	S	S	S	S	S
14	S	S	S	S	(C)	(C)	(C)	(C)	(C)	(C)	(C)	(C)
15	S	S	S	S	S	S	S	C	(C)	(C)	(C)	(C)
16	S	S	S	S	S	S	S	S	S	S	S	S
17	(C)	(C)	(C)	(C)	S	C	C	C	S	S	S	C
18	C	C	C	C	S	S	S	S	S	S	S	S
19	C	C	C	C	C	C	C	C	S	S	S	S
20	S	S	S	S	(C)	(C)	(C)	(C)	(S)	(S)	(S)	(C)
21	S	S	S	S	C	C	C	S	C	C	C	C
22	C	C	C	C	C	C	C	C	S	S	S	S
23	C	C	C	C	S	S	S	S	S	S	S	S
24	S	C	C	C	S	S	S	S	S	S	S	S
25	S	S	S	S	S	S	S	S	S	S	S	S
26	S	S	S	C	S	S	S	S	S	S	S	S
27	(C)	(C)	(C)	(C)	S	S	S	S	C	C	C	C
28	(C)	(C)	(C)	(C)	S	S	S	C	(S)	(S)	(S)	(S)
29	C	C	C	S	(S)	(S)	(S)	(C)	C	C	C	C
30	C	C	C	C	C	C	C	C	S	S	S	S
31	C	C	C	C	C	C	C	C	...	...	...	...
C	15	16	16	20	10	11	11	14	8	8	8	10
S	15	14	14	11	21	20	20	17	20	21	21	20
M	1	1	1	...	...	...	...	...	2	1	1	...
G	...	...	...	...	...	...	...	...	...	...	...	...
V. G.	...	...	...	...	...	...	...	...	...	...	...	...
Trace lost	...	...	...	...	...	...	...	...	...	...	...	...

Date.	October.				November.				December.				Remarks.
1913	D	B	T	K	D	B	T	K	D	B	T	K	
1	(C)	(C)	(C)	(C)	S	S	S	S	C	C	C	C	
2	(C)	(C)	(C)	(C)	M	M	M	M	S	S	S	S	
3	C	C	C	C	S	S	S	S	C	C	C	C	
4	C	C	C	C	C	C	C	C	S	S	S	S	
5	S	S	S	S	C	C	C	C	S	S	S	S	
6	S	S	S	S	S	S	S	S	C	C	C	C	
7	S	S	S	S	S	S	S	S	S	S	S	S	
8	S	S	S	S	S	S	S	S	S	S	S	C	
9	S	S	S	S	C	C	C	C	S	S	S	S	
10	S	S	S	S	(C)	(C)	(C)	(C)	(C)	(C)	(C)	(C)	
11	S	S	S	S	C	C	C	C	(C)	(C)	(C)	(C)	
12	S	S	S	S	S	S	S	C	C	C	C	C	
13	S	S	S	S	S	S	S	S	(C)	(C)	(C)	(C)	
14	S	C	C	C	(C)	(C)	(C)	(C)	C	C	C	C	
15	S	S	S	S	(C)	(C)	(C)	(C)	C	C	C	C	
16	S	S	S	C	(C)	(C)	(C)	(C)	C	C	C	C	
17	C	C	C	C	S	S	S	S	C	C	C	C	
18	S	S	S	S	S	S	S	S	S	S	S	C	
19	S	S	S	S	S	S	S	S	S	S	S	S	
20	S	S	S	S	C	C	C	C	C	C	C	C	
21	C	C	C	C	C	C	C	C	(C)	(C)	(C)	(C)	
22	C	C	C	C	S	S	S	S	C	C	C	C	
23	(C)	(C)	(C)	(C)	(C)	(C)	(C)	(C)	(C)	(C)	(C)	(C)	
24	(C)	(C)	(C)	(C)	S	C	S	C	C	C	C	C	
25	C	C	C	C	C	C	C	C	S	S	S	S	
26	S	S	S	S	S	S	S	S	S	S	S	S	
27	C	C	C	C	S	S	S	S	S	S	S	S	
28	(S)	(S)	(S)	(S)	S	S	S	S	C	C	C	C	
29	C	C	C	C	S	S	S	S	C	C	C	C	
30	C	C	C	C	C	C	C	C	C	C	C	C	
31	S	S	S	S	...	...	...	...	C	C	C	C	
C	13	14	14	15	13	14	13	15	20	20	20	22	
S	18	17	17	16	16	15	16	14	11	11	11	9	
M	...	...	...	...	1	1	1	1	...	...	...	...	
G	...	...	...	...	...	...	...	...	...	...	...	...	
V. G.	...	...	...	...	...	...	...	...	...	...	...	...	
Trace lost	...	...	...	...	...	...	...	...	...	...	...	...	

(C)=Selected quiet day. C=Calm. S=Slight. M=Moderate. G=Great. V. G.=Very Great. —=Trace lost.

C.—Abstract showing approximate magnetic values at stations observed at by No. 18 Party during season 1913-14.

DETAIL SURVEY STATIONS.

Serial No.	Name of Station.	Latitude.			Longitude.			Dip.		Declination.			Horizontal Force.	Remarks.
		°	′	″	°	′	″	°	′		°	′	C. G. S.	
372D	Bhosri	18	37	30	73	50	20	23	1	W.	0	9	0·3719	H is derived from mean M_0 throughout.
373D	Lohagaon	18	36	0	73	55	10	23	5	E.	0	20	·3683	
374D	Mundhwa	18	32	0	73	55	40	22	57	W.	0	3	·3698	
375D	Dhabdhabi	18	29	40	73	59	0	22	19	,,	0	4	·3709	
376D	Alandi	18	27	0	74	3	20	24	12	,,	0	49	·3670	
377D	Walti	18	26	20	74	6	0	22	46	,,	0	22	·3707	
378D	Amla	18	24	40	74	9	50	23	1	,,	0	8	·3699	
379D	Goroli	18	24	20	74	4	50	22	46	,,	0	23	·3714	
380D	Wanpuri	18	22	20	74	3	40	22	59	E.	0	1	·3694	
381D	Devaghat	18	24	40	74	0	0	22	24	W.	0	14	·3712	
382D	Urli-Devachi	18	27	30	73	57	0	22	50	E.	0	2	·3693	
383D	Kondhwa	18	26	50	73	53	0	23	49	W.	0	4	·3712	
384D	Wanowri	18	30	10	73	53	30	22	53	,,	0	16	·3709	
385D	Yerowda	18	32	50	73	52	50	24	1	E.	0	6	·3649	
386D	Kothrad	18	30	20	73	48	20	23	38	W.	0	5	·3706	
387D	Sus	18	33	30	73	44	10	23	3	E.	0	4	·3685	
388D	Maranji	18	36	40	73	42	0	23	17	,,	0	6	·3709	
389D	Bhara	18	32	10	73	40	10	23	46	,,	0	0	·3698	
390D	Riha	18	34	40	73	38	10	22	23	,,	0	27	·3720	
391D	Kamboli	18	36	10	73	35	20	23	5	,,	0	24	·3715	
392D	Kolwan	18	34	30	73	31	30	28	5	,,	0	18	·3714	
393D	Kāsig	18	37	10	73	30	40	23	3	,,	0	13	·3731	
394D	Morva	18	38	50	73	26	0	22	59	W.	0	1	·3693	
395D	Majgaon	18	40	20	73	28	30	22	51	E.	0	9	·3698	
396D	Yelgola	18	39	30	73	32	20	22	60	,,	0	17	·3696	
397D	Adhala Khurd	18	38	50	73	36	50	23	35	W.	0	14	3699	
398D	Bhaja	18	43	50	73	28	0	23	42	,,	0	22	·3706	
399D	Sakal Pathar	18	42	0	73	22	40	24	35	E.	0	7	·3694	
400D	Deolali	19	56	40	73	49	0	25	44	,,	0	26	·3672	
401D	Wargaon-Pingla	19	52	20	73	52	20	26	6	,,	0	8	·3653	
402D	Pasta	19	50	50	73	56	30	25	36	,,	1	13	·3657	
403D	Patola	19	47	0	73	59	10	25	28	W.	0	8	·3666	
404D	Musalgaon	19	50	10	74	3	20	25	21	E.	0	6	·3672	
405D	Baragaon-Pimpri	19	54	0	74	2	30	26	53	W.	0	21	·3618	
406D	Jaigaon	19	55	40	73	58	10	25	59	E.	0	23	·3655	
407D	Kotamgaon	19	57	10	73	53	10	26	18	,,	0	3	·3646	

Abstract showing approximate magnetic values at stations observed at by No. 18 Party during season 1913-14.

REPEAT STATIONS.

Serial No.	NAME OF STATIONS.	Latitude. °	′	″	Longitude. °	′	″	Dip. °	′	Declination.	°	′	Horizontal Force. C. G. S.	REMARKS.
II	Karāchi . .	24	49	50	67	2	2	35	4	E.	1	38	0·3448	H is derived from mean M_0 throughout.
IV	Bahāwalpur .	29	23	27	71	40	37	42	54	,,	2	43	·3304	
V	Rāwalpindi . .	33	35	16	73	3	6	48	59	,,	3	34	·3097	
VI	Bharatpur . .	27	13	27	77	29	28	39	29	,,	1	40	·3451	
VII	Bangalore . .	12	59	35	77	35	58	10	27	W.	1	6	·3836	
VIII	Dhārwār . .	15	27	26	74	59	35	16	8	,,	0	37	·3778	
X	Fyzābād . .	26	47	27	82	7	40	38	34	E.	1	21	·3532	
XI	Sambalpur . .	21	28	3	83	58	24	28	28	,,	0	18	·3744	
XII	Waltair . .	17	42	57	83	19	1	21	48	W.	0	18	·3804	
XIII	Darjeeling . .	26	59	49	88	16	39	38	47		—		·3576	
XIV	Gayā . . .	24	46	30	84	58	54	34	49	E.	0	40	·3671	
XV	Secunderābād .	17	27	11	78	29	16	20	51	W.	0	8	·3807	
XVI	Bhusāwal . .	21	2	46	75	47	18	27	49	E.	0	30	·3684	
XIX	Lashio . .	22	56	47	97	44	40	31	22	,,	0	15		
XX	Akyab . . .	20	7	53	92	53	18	25	42	,,	0	13	·3854	
XXI	Silchar or Cāchār .	24	49	43	92	47	21	34	58	,,	0	39	·3706	
XXII	Dibrugarh . .	27	29	24	94	55	40	39	46	,,	0	45	·3593	
46	Ruk Junction .	27	48	23	68	38	20	40	12	,,	1	58	·3342	
71	Lahore . .	31	35	50	74	18	50	46	37	,,	2	45	·3196	
88	Peshāwar . .	34	0	40	71	33	40	49	33	,,	3	46	·3067	
92	Kundiān . .	32	27	30	71	28	20	48	15	,,	3	23	·3086	
124	Bīkaner . .	28	0	40	73	18	50	40	41	,,	1	54	·3382	
130	Ajmer . .	26	27	30	74	38	30	37	58	,,	1	47	·3462	
134	Mīrpur Khās .	25	31	40	69	0	40	36	21	,,	1	45	·3441	
172	Dhond . .	18	28	0	74	35	10	22	54	,,	0	12	·3716	
175	Hotgi . .	17	33	40	76	0	20	20	58	W.	0	4	·3758	
181	Guntakal . .	15	10	48	77	22	57	15	51	,,	0	40	·3807	
186	Arkonam . .	13	4	30	79	40	20	10	42	,,	1	11	·3863	
199	Cannanore . .	11	52	30	75	22	0	8	56	,,	1	34	·3815	
207	Birūr . . .	13	35	50	75	58	10	12	11	,,	0	54	·3805	
216	Mirāj . . .	16	49	10	74	38	10	19	56	,,	0	20	·3776	
223	Manmād . .	20	14	40	74	26	20	26	36	E.	0	40	·3665	
232	Delhi (*a*) . .	28	40	20	77	14	20	41	54	,,	1	49	·3396	
283	Sirsa . . .	29	32	10	75	2	40	43	6	,,	2	23	·3331	
328 (*a*)	Tinnevelly . .	8	44	0	77	42	30	1	13	W.	1	53	·3805	
332	Mandapam . .	9	16	50	79	8	30	1	52	,,	1	43	·3836	
337	Tanjore . .	10	46	40	79	8	20	5	0	,,	1	38	·3837	

Abstract showing approximate magnetic values at stations observed at by No. 18 Party during season 1913-14—concluded.

REPEAT STATIONS—*concluded.*

Serial No.	NAME OF STATION.	Latitude.			Longitude.			Dip.		Declination.			Horizontal Force.	REMARKS.
		°	′		°	′	″	°	′		°	′	C. G. S.	
375	Parbhani	19	15	20	76	46	50	25	9	E.	0	27	0·3713	H is derived from mean M_0 throughout.
384	Bezwāda	16	31	0	80	36	50	18	11	W.	0	46	·3830	
483	Mānikpur	25	3	10	81	5	20	35	32	E.	1	2	·3591	
489	Monghyr	25	23	10	86	27	50	36	1	„	0	52	·3632	
500	Sini	22	47	0	85	56	50	30	56	„	0	33	·3748	
557	Indore	22	42	8	75	52	40	31	13	„	0	34	·3681	
573	Cawnpore	26	27	0	80	21	0	37	58	„	1	25	·3530	
598	Kāthgodām	29	15	19	79	32	50	42	49	„	2	1	·3376	
692	Balasore	21	30	6	86	54	40	28	36	„	0	12	·3773	
699	Berhampur (Ganjām.)	19	18	10	84	48	40	24	4	W.	0	9	·3819	
710	Cumbum	15	35	50	79	6	40	16	40	„	1	3	·3824	
746	Chānda	19	57	50	79	17	40	25	39	E.	0	11	·3749	
765	Raipur	21	15	50	81	38	20	28	29	„	0	18	·3725	
779	Amrāoti	20	55	30	77	45	50	28	8	„	0	3	·3648	
831	Sāntāhār	24	48	10	88	59	20	34	52	„	0	50	·3682	
871	Lāksām	23	15	40	91	7	20	31	54	„	0	29	·3749	
961	Mandalay (*b*)	22	0	14	96	6	30	29	25	„	0	13	·3821	
975	Myitkyinā	25	23	20	97	24	10	36	17	„	1	8	·3633	
977	Bhamo	24	15	30	97	13	10	33	52	„	0	28	·3748	
1068	Prome	18	49	40	95	13	20	22	50	„	0	2	·3903	
1071	Bassein	16	46	20	94	44	30	18	11	W.	0	4	·3942	
1195	Moulmein	16	29	40	97	37	30	17	41	E.	0	7	·3951	
1331	Mussoorie	30	27	12	78	5	10	44	31	„	2	25	·3307	
1338	Barmer	25	44	35	71	26	40	36	59	„	1	33	·3436	

OLD STATIONS RE-OBSERVED.

Serial No.	Name of Station.	Latitude.			Longitude.			Dip.		Declination.			Horizontal Force.	Remarks.
170	Lonāvla (*a*)	18	44	40	73	23	40	23	30	E.	0	20	0·3735	H is derived from mean M_0 throughout.
171	Kirkee (*a*)	18	33	30	73	50	0	23	17	W.	0	10	·3693	

NOTE.—The above values of Dip, Declination, and Horizontal Force are uncorrected for secular change, diurnal variation, instrumental differences, etc., and are to be considered as preliminary values only.

All Longitudes are referable to that of Madras Observatory taken at the value 80° 14′ 54″ east from Greenwich.

D.—Table of results at Dehra Dūn.

Hourly Means of the Declination as determined at Dehra Dūn from all available days in 1913.

Hours.	Mid.	1	2	3	4	5	6	7	8	9	10	11	Noon.	13	14	15	16	17	18	19	20	21	22	23	Mid.	Means.
E. 2° + Winter.																										
Months.	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′
January .	24·2	24·2	23·9	24·0	23·8	23·6	23·4	23·4	24·4	25·1	24·9	23·9	23·3	23·2	23·5	23·7	24·2	24·4	24·3	24·3	24·3	24·3	24·2	24·2	24·2	24·0
February .	24·1	24·1	24·1	23·9	23·7	23·4	23·3	23·1	23·6	24·4	24·6	24·2	23·7	23·4	23·7	23·8	23·8	23·8	23·8	24·0	23·9	23·8	24·0	24·0	24·1	23·8
March .	23·5	23·5	23·4	23·4	23·3	23·2	23·2	23·7	24·7	25·1	24·8	23·4	22·3	21·6	21·8	22·6	23·2	23·4	23·3	23·2	23·1	23·2	23·3	23·3	23·4	23·3
October .	21·4	21·4	21·2	21·1	21·1	20·9	20·9	21·6	22·4	22·3	21·2	20·1	19·3	19·3	20·0	20·9	21·4	21·2	21·1	21·1	21·1	21·1	21·2	21·3	21·4	21·0
November .	21·1	21·1	21·0	20·9	20·7	20·5	20·3	20·5	20·9	21·1	20·8	20·3	20·0	20·3	20·9	21·0	20·9	20·9	21·0	21·0	20·9	21·0	21·1	21·1	21·1	20·8
December .	20·7	20·6	20·5	20·4	20·2	20·0	19·9	19·7	19·7	20·1	20·3	20·0	19·9	20·3	20·8	21·1	20·9	20·8	20·8	20·7	20·7	20·5	20·6	20·6	20·7	20·4
Means .	22·5	22·5	22·4	22·3	22·1	21·9	21·8	22·0	22·6	23·0	22·8	22·0	21·4	21·4	21·8	22·2	22·4	22·4	22·4	22·4	22·3	22·3	22·4	22·4	22·5	22·2
E. 2° + Summer.																										
April .	22·3	23·3	23·3	23·1	23·0	23·0	23·4	24·5	25·4	25·5	24·2	22·8	20·9	20·5	20·9	21·7	22·5	22·9	22·8	22·7	22·7	22·8	23·0	23·1	23·1	22·9
May . .	22·9	23·0	23·1	23·0	23·0	23·2	24·3	25·1	25·3	24·3	22·5	20·9	19·9	19·7	20·4	21·3	22·1	22·6	22·6	22·4	22·3	22·4	22·6	22·7	22·8	22·6
June . .	22·5	22·7	22·8	22·8	22·9	23·3	24·5	25·3	25·1	24·0	22·3	20·8	19·7	19·5	19·9	20·6	21·3	22·0	22·2	22·0	21·9	22·0	22·2	22·4	22·5	22·3
July . .	22·2	22·4	22·5	22·6	22·6	22·8	23·9	24·7	24·7	24·0	22·7	21·1	20·0	19·5	19·6	20·1	20·8	21·5	22·0	21·9	21·8	21·8	22·0	22·1	22·2	22·1
August .	21·9	22·1	22·1	22·2	22·3	22·5	23·6	24·4	24·6	23·3	21·6	20·0	19·2	19·0	19·5	20·5	21·3	21·8	21·8	21·6	21·5	21·5	21·7	21·9	21·9	21·8
September	21·6	21·7	21·7	21·7	21·7	21·7	22·3	23·3	23·8	23·2	21·6	19·9	18·8	18·6	19·3	20·7	21·5	21·8	21·6	21·4	21·3	21·3	21·4	21·5	21·6	21·4
Means .	22·4	22·5	22·6	22·6	22·6	22·8	23·7	24·6	24·8	24·1	22·5	20·8	19·8	19·5	19·9	20·8	21·6	22·1	22·2	22·0	21·9	22·0	22·2	22·3	22·4	22·2

Diurnal Inequality of the Declination at Dehra Dûn as deduced from the preceding Table

Hours.	Mid.	1	2	3	4	5	6	7	8	9	10	11	Noon.	13	14	15	16	17	18	19	20	21	22	23	Mid.
													Winter.												
1913 Months.	′	′	′	′	′	′	′	′	′	′		′	′	′	′	′	′	′	′		′	′	′	′	′
January	−0·2	+0·2	−0·1	0	−0·2	−0·4	−0·6	−0·6	+0·4	+1·1	+0·9	−0·1	−0·7	−0·8	−0·5	−0·3	+0·2	+0·4	+0·3	+0·3	+0·3	+0·3	+0·2	+0·2	+0·2
February	+0·3	+0·3	+0·3	+0·1	−0·1	−0·4	−0·5	−0·7	−0·2	+0·6	+0·8	+0·4	−0·1	−0·4	−0·1	0	0	0	0	+0·2	+0·1	0	+0·2	+0·2	+0·3
March	+0·2	+0·2	+0·1	+0·1	−0·1	−0·1	−0·1	+0·4	+1·4	+1·8	+1·5	+0·1	−1·0	−1·7	−1·5	−0·7	−0·1	+0·1	0	−0·1	−0·2	−0·1	0	0	+0·1
October	+0·4	+0·4	+0·2	+0·1	+0·1	−0·1	−0·1	+0·6	+1·4	+1·3	+0·2	−0·9	−1·7	−1·7	−1·0	−0·1	+0·4	+0·2	+0·1	+0·1	+0·1	+0·1	+0·2	+0·3	+0·4
November	+0·3	+0·3	+0·2	+0·1	−0·1	−0·3	−0·5	−0·3	+0·1	+0·3	0	−0·5	−0·8	−0·5	+0·1	+0·2	+0·1	+0·1	+0·2	+0·2	+0·1	+0·2	+0·3	+0·3	+0·3
December	+0·3	+0·2	+0·1	0	−0·2	−0·4	−0·5	−0·7	−0·7	−0·3	−0·1	−0·4	−0·5	−0·1	+0·4	+0·7	+0·5	+0·4	+0·4	+0·3	+0·3	+0·1	+0·2	+0·2	+0·3
Means	+0·3	+0·3	+0·2	+0·1	−0·1	−0·3	−0·4	−0·2	+0·4	+0·8	+0·6	−0·2	−0·8	−0·8	−0·4	0	+0·2	+0·2	+0·2	+0·2	+0·1	+0·1	+0·2	+0·2	+0·3
													Summer.												
April	+0·4	+0·4	+0·4	+0·2	+0·1	+0·1	+0·5	+1·6	+2·5	+2·6	+1·3	−0·6	−2·0	−2·4	−2·0	−1·2	−0·4	0	−0·1	−0·2	−0·2	−0·1	+0·1	+0·2	+0·2
May	+0·3	+0·4	+0·5	+0·4	+0·4	+0·6	+1·7	+2·5	+2·7	+1·7	−0·1	−1·7	−2·7	−2·9	−2·2	−1·3	−0·5	0	0	−0·2	−0·3	−0·2	0	+0·1	+0·2
June	+0·2	+0·4	+0·5	+0·5	+0·6	+1·0	+2·2	+3·0	+2·8	+1·7	0	−1·5	−2·6	−2·8	−2·4	−1·7	−1·0	−0·3	−0·1	−0·3	−0·4	−0·3	−0·1	+0·1	+0·2
July	+0·1	+0·3	+0·4	+0·5	+0·5	+0·7	+1·8	+2·6	+2·6	+1·9	+0·6	−1·0	−2·1	−2·6	−2·5	−2·0	−1·3	−0·6	−0·1	−0·2	−0·3	−0·3	−0·1	0	+0·1
August	+0·1	+0·3	+0·3	+0·4	+0·5	+0·7	+1·8	+2·6	+2·8	+1·5	−0·2	−1·8	−2·6	−2·8	−2·3	−1·3	−0·5	0	0	−0·2	−0·3	−0·3	−0·1	+0·1	+0·1
September	+0·2	+0·3	+0·3	+0·3	+0·3	+0·3	+0·9	+1·9	+2·4	+1·8	+0·2	−1·5	−2·6	−2·8	−2·1	−0·7	+0·1	+0·4	+0·2	0	−0·1	−0·1	0	+0·1	+0·2
Means	+0·2	+0·3	+0·4	+0·4	+0·4	+0·6	+1·5	+2·4	+2·6	+1·9	+0·3	−1·4	−2·4	−2·7	−2·3	−1·4	−0·6	−0·1	0	−0·2	−0·3	−0·2	0	+0·1	+0·2

NOTE.—When the sign is + the magnet points to the East, and when — to the West of the mean position.

Hourly Means of Horizontal Force in C. G. S. Units (Corrected for temperature) at Dehra Dūn from all available days in 1913.

Hours.	Mid.	1	2	3	4	5	6	7	8	9	10	11	Noon.	13	14	15	16	17	18	19	20	21	22	23	Mid.	Means.
·33000 C. G. S. +													Winter.													
Months.	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ
January .	197	196	199	198	198	200	202	204	206	205	200	201	205	205	203	202	200	197	196	193	194	195	195	195	197	199
February .	196	197	197	197	197	199	200	204	208	212	214	216	214	211	208	201	197	194	194	195	195	195	194	193	196	201
March .	195	194	195	195	196	196	196	196	199	199	209	212	213	213	209	206	200	196	196	195	193	193	194	194	196	199
October .	176	176	177	177	178	178	179	178	175	174	177	183	186	185	182	177	176	173	174	173	174	174	174	175	176	177
November .	174	174	174	175	176	177	178	181	185	186	188	189	190	186	180	177	177	176	176	174	174	173	172	173	174	179
December .	173	174	174	174	176	177	179	183	189	192	192	191	189	186	183	180	178	176	175	174	172	173	174	174	173	180
Means .	185	185	186	186	187	188	189	191	194	195	197	199	200	198	194	191	188	185	185	184	184	184	184	184	185	189
													Summer.													
April .	190	190	190	190	193	192	192	188	186	188	193	201	208	21	210	204	199	194	191	189	189	191	191	192	193	194
May .	194	195	196	196	195	196	197	191	186	187	194	204	211	214	211	207	201	195	194	194	194	193	194	195	195	197
June .	198	198	198	198	199	199	199	197	194	193	199	205	209	211	209	203	202	197	193	194	195	196	197	197	198	199
July .	193	195	194	194	195	194	195	194	193	193	196	199	203	206	207	204	199	193	190	189	191	191	192	193	193	196
August .	188	189	188	189	188	188	187	183	178	178	183	190	196	200	200	198	194	189	186	187	186	187	187	188	188	189
September .	180	180	181	181	182	182	181	176	171	169	170	177	188	192	193	187	182	178	177	176	176	178	180	180	181	180
Means .	191	191	191	191	192	192	192	188	185	185	189	196	203	206	205	200	196	191	189	188	189	189	190	191	191	192

Diurnal Inequality of the Horizontal Force at Dehra Dūn as deduced from the preceding Table.

Hours.	Mid.	1	2	3	4	5	6	7	8	9	10	11	Noon.	13	14	15	16	17	18	19	20	21	22	23	Mid.
Winter.																									
1913 Months.	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ
January	−2	−3	0	−1	−1	+1	+3	+5	+7	+6	+1	+2	+6	+6	+4	+3	+1	−2	−3	−6	−5	−4	−4	−4	−2
February	−5	−4	−4	−4	−4	−2	−1	+3	+7	+11	+13	+15	+13	+10	+5	0	−4	−7	−7	−6	−6	−6	−7	−8	−5
March	−4	−5	−4	−4	−3	−3	−3	−3	0	0	+10	+13	+14	+14	+10	+7	+1	−3	−3	−4	−6	−6	−5	−5	−3
October	−1	−1	0	0	+1	+1	+2	+1	−2	−3	0	+6	+9	+8	+5	0	−1	−4	−3	−4	−3	−3	−3	−2	−1
November	−5	−5	−5	−4	−3	−2	−1	+2	+6	+7	+9	+10	+11	+7	+1	−2	−2	−3	−3	−5	−5	−6	−7	−6	−5
December	−7	−6	−6	−6	−4	−3	−1	+3	+9	+12	+12	+11	+9	+6	+3	0	−2	−4	−5	−6	−8	−7	−6	−6	−7
Means	−4	−4	−3	−3	−2	−1	0	+2	+5	+6	+8	+10	+11	+9	+5	+2	−1	−4	−4	−5	−5	−5	−5	−5	−4
Summer.																									
April	−4	−4	−4	−4	−1	−2	−2	−6	−8	−6	−1	+7	+14	+17	+16	+10	+5	0	−3	−5	−5	−3	−3	−2	−1
May	−3	−2	−1	−1	−2	−1	0	−6	−11	−10	−3	+7	+14	+17	+14	+10	+4	−2	−3	−3	−3	−4	−3	−2	−2
June	−1	−1	−1	−1	0	0	0	−2	−5	−6	0	+6	+10	+12	+10	+9	+3	−2	−6	−5	−4	−3	−2	−2	−1
July	−3	−1	−2	−2	−1	−2	−1	−2	−3	−3	0	+3	+7	+10	+11	+8	+3	−3	−6	−7	−5	−5	−4	−3	−3
August	−1	0	−1	0	−1	−1	−2	−6	−11	−11	−6	+1	+7	+11	+11	+9	+5	0	−3	−2	−3	−2	−2	−1	−1
September	0	0	+1	+1	+2	+2	+1	−4	−9	−11	−10	−3	+8	+12	+13	+7	+2	−2	−3	−4	−4	−2	0	0	+1
Means	−1	−1	−1	−1	0	0	0	−4	−7	−7	−3	+4	+11	+14	+13	+8	+4	−1	−3	−4	−3	−3	−2	−1	−1

NOTE.—When the sign is + the H. F. is greater, and when — it is less than the mean.

Hourly Means of Vertical Force in C. G. S. Units (Corrected for temperature) at Dehra Dūn from all available days in 1913.

·32000 +

Hours.	Mid.	1	2	3	4	5	6	7	8	9	10	11	Noon.	13	14	15	16	17	18	19	20	21	22	23	Mid.	Means.
Winter.																										
Months.	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ
January .	300	300	300	300	300	300	300	300	302	301	296	393	294	296	297	299	301	300	301	300	301	301	301	301	301	299
February .	329	329	329	328	328	328	328	329	330	330	328	326	324	324	327	327	328	329	329	330	330	330	330	330	330	328
March .	339	339	339	338	338	338	339	340	341	339	334	329	328	330	335	337	338	338	337	337	338	338	339	339	339	337
October .	384	384	384	384	384	383	384	386	385	381	377	374	375	379	384	387	387	385	386	387	388	387	388	388	388	384
November .	383	383	383	383	382	382	382	383	383	381	378	378	379	381	382	383	384	384	385	385	384	384	385	385	384	383
December .	393	393	393	393	394	394	394	393	395	396	394	390	392	395	395	395	394	394	394	395	395	395	396	396	396	394
Means .	355	355	355	254	354	354	355	355	356	355	351	348	349	351	353	355	355	355	355	356	356	356	357	357	356	354
Summer.																										
April . .	349	349	349	349	349	349	351	352	352	346	337	335	337	341	346	349	350	350	350	350	351	352	351	352	352	348
May . .	361	361	362	361	362	363	366	363	358	351	346	344	347	351	356	360	362	362	362	362	363	363	364	364	364	359
June . .	367	367	367	367	368	369	373	370	364	358	353	350	352	355	359	363	366	367	367	367	368	368	369	369	369	364
July . .	368	368	368	368	368	369	372	370	367	361	357	356	357	359	363	366	370	371	372	371	372	373	374	374	373	567
August .	373	374	373	373	373	374	377	376	372	367	362	359	363	367	372	374	375	374	374	374	375	376	376	376	376	372
September .	376	376	376	376	376	376	378	379	276	371	367	364	366	370	374	377	378	377	376	377	378	278	379	378	378	375
Means	366	366	366	366	366	367	370	368	365	359	354	351	354	357	362	365	367	367	367	367	368	368	369	369	369	364

Diurnal Inequality of the Vertical Force at Dehra Dūn as deduced from the preceding Table.

Hours.	Mid.	1	2	3	4	5	6	7	8	9	10	11	Noon.	13	14	15	16	17	18	19	20	21	22	23	Mid.
Winter.																									
1913 Months.	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ
January	+1	+1	+1	+1	+1	+1	+1	+1	+3	+2	−3	−6	−5	−3	−2	0	+2	+1	+2	+1	+2	+2	+2	+2	+2
February	+1	+1	+1	0	0	0	0	+1	+2	+2	0	−2	−4	−4	−1	−1	0	+1	+1	+2	+2	+2	+2	+2	+2
March	+2	+2	+2	+1	+1	+1	+2	+3	+4	+2	−3	−8	−9	−7	−2	0	+1	+1	0	0	+1	+1	+2	+2	+2
October	0	0	0	0	0	−1	0	+2	+1	−3	−7	−10	−9	−5	0	+3	+3	+1	+2	+3	+4	+3	+4	+4	+4
November	0	0	0	0	−1	−1	−1	0	0	−2	−5	−5	−4	−2	−1	0	+1	+1	+2	+2	+1	+1	+2	+2	+1
December	−1	−1	−1	−1	0	0	0	−1	+1	+2	0	−4	−2	+1	+1	+1	0	0	0	+1	+1	+1	+2	+2	+2
Means	+1	+1	+1	0	0	0	+1	+1	+2	+1	−3	−6	−5	−3	−1	+1	+1	+1	+1	+2	+2	+2	+3	+3	+2
Summer.																									
April	+1	+1	+1	+1	+1	+1	+3	+4	+4	−2	−11	−13	−11	−7	−2	+1	+2	+2	+2	+2	+3	+4	+3	+4	+4
May	+2	+2	+3	+2	+3	+4	+7	+4	−1	−8	−13	−15	−12	−8	−3	+1	+3	+3	+3	+3	+4	+4	+5	+5	+5
June	+3	+3	+3	+3	+4	+5	+9	+6	0	−6	−11	−14	−12	−9	−5	−1	+2	+3	+3	+3	+4	+4	+5	+5	+5
July	+1	+1	+1	+1	+1	+2	+5	+3	0	−6	−10	−11	−10	−8	−4	−1	+3	+4	+5	+4	+5	+6	+7	+7	+6
August	+1	+2	+1	+1	+1	+2	+5	+4	0	−5	−10	−13	−9	−5	0	+2	+3	+2	+2	+2	+3	+4	+4	+4	+4
September	+1	+1	+1	+1	+1	+1	+3	+4	+1	−4	−8	−11	−9	−5	−1	+2	+3	+2	+1	+2	+3	+3	+4	+3	+3
Means	+2	+2	+2	+2	+2	+3	+6	+4	+1	−5	−10	−13	−10	−7	−2	+1	+3	+3	+3	+3	+4	+4	+5	+5	+5

NOTE.—When the sign is + the V. F. is greater, and when − it is less than the mean.

Hourly Means of the Dip as determined at Dehra Dūn from all available days in 1913.

Hours.	Mid.	1	2	3	4	5	6	7	8	9	10	11	Noon.	13	14	15	16	17	18	19	20	21	22	23	Mid.	Means.
			N. 44° +										Winter.													
Months.	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′
January .	12·9	13·0	12·8	12·9	12·9	12·8	12·7	12·6	12·6	12·6	12·6	12·4	12·2	12·3	12·4	12·6	12·8	12·9	13·0	13·1	13·2	13·1	13·1	13·1	13·0	12·8
February .	14·5	14·5	14·5	14·4	14·4	14·3	14·3	14·1	14·0	13·7	13·5	13·3	13·4	13·5	13·9	14·2	14·4	14·6	14·6	14·7	14·7	14·7	14·7	14·7	14·6	14·2
March .	15·1	15·2	15·1	15·1	15·0	15·0	15·1	15·1	15·0	14·9	14·1	13·7	13·6	13·7	14·1	14·4	14·8	15·0	14·9	15·0	15·1	15·1	15·2	15·2	15·1	14·8
October .	18·5	18·5	18·4	18·4	18·4	18·3	18·3	18·5	18·6	18·4	18·1	17·6	17·5	17·7	18·2	18·6	18·7	18·7	18·7	18·8	18·8	18·7	18·8	18·7	18·7	18·4
November .	18·5	18·5	18·5	18·5	18·4	18·3	18·3	18·2	18·0	17·8	17·5	17·5	17·5	17·8	18·1	18·4	18·4	18·5	18·5	18·6	18·6	18·7	18·7	18·7	18·6	18·8
December .	19·1	19·0	19·0	19·0	19·0	18·9	18·9	18·6	18·4	18·3	18·2	18·0	18·3	18·6	18·7	18·9	18·9	19·0	19·0	19·2	19·3	19·2	19·2	19·2	19·3	18·8
Means .	16·4	16·5	16·4	16·4	16·4	16·3	16·3	16·2	16·1	16·0	15·7	15·4	15·4	15·6	15·9	16·2	16·3	16·5	16·5	16·6	16·6	16·6	16·6	16·6	16·6	16·2
													Summer.													
April .	15·9	15·9	15·9	15·9	15·7	15·8	15·9	16·2	16·3	15·8	15·1	14·6	14·3	14·4	14·7	15·2	15·4	15·7	15·9	16·0	16·1	16·0	16·0	16·0	15·9	15·6
May .	16·3	16·3	16·3	16·2	16·4	16·3	16·4	16·6	16·6	16·2	15·5	14·9	14·7	14·8	15·2	15·6	16·0	16·4	16·4	16·4	16·4	16·5	16·5	16·4	16·4	16·1
June .	16·4	16·4	16·4	16·4	16·4	16·5	16·7	16·6	16·5	16·2	15·6	15·2	15·1	15·1	15·4	15·7	16·2	16·5	16·7	16·6	16·7	16·6	16·6	16·6	16·6	16·2
July .	16·8	16·7	16·7	16·7	16·7	16·8	16·9	16·8	16·7	16·4	16·0	15·8	15·6	15·6	15·8	16·1	16·5	16·9	17·1	17·1	17·1	17·1	17·1	17·1	17·0	16·6
August .	17·3	17·3	17·3	17·2	17·3	17·3	17·5	17·7	17·7	17·5	17·0	16·4	16·3	16·3	16·6	16·8	17·1	17·3	17·5	17·4	17·5	17·5	17·5	17·4	17·4	17·2
September .	17·8	17·8	17·8	17·8	17·7	17·7	17·9	18·2	18·3	18·2	17·9	17·3	16·9	16·9	17·1	17·5	17·9	18·0	18·0	18·1	18·2	18·1	18·0	17·9	17·9	17·8
Means .	16·8	16·7	16·7	16·7	16·7	16·7	16·9	17·0	17·0	16·7	16·2	15·7	15·5	15·5	15·8	16·2	16·5	16·8	16·9	16·9	17·0	17·0	17·0	16·9	16·9	16·6

Diurnal Inequality of the Dip at Dehra Dūn as deduced from the preceding Table.

Hours.	Mid.	1	2	3	4	5	6	7	8	9	10	11	Noon.	13	14	15	16	17	18	19	20	21	22	23	Mid.
Winter.																									
1913 Months.	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′
January	+0·1	+0·2	0	+0·1	+0·1	0	−0·1	−0·2	−0·2	−0·2	−0·2	−0·4	−0·6	−0·5	−0·4	−0·2	0	+0·1	+0·2	+0·3	+0·4	+0·3	+0·3	+0·3	+0·2
February	+0·3	+0·3	+0·3	+0·2	+0·2	+0·1	+0·1	−0·1	−0·2	−0·5	−0·7	−0·9	−0·8	−0·7	−0·3	0	+0·2	+0·4	+0·4	+0·5	+0·5	+0·5	+0·5	+0·5	+0·4
March	+0·3	+0·4	+0·3	+0·3	+0·2	+0·2	+0·3	+0·3	+0·2	+0·1	−0·7	−1·1	−1·2	−1·1	−0·7	−0·4	0	+0·2	+0·1	+0·2	+0·3	+0·3	+0·4	+0·4	+0·3
October	+0·1	+0·1	0	0	0	−0·1	−0·1	+0·1	+0·2	0	−0·3	−0·8	−0·9	−0·7	−0·2	+0·2	+0·3	+0·3	+0·3	+0·4	+0·4	+0·3	+0·4	+0·3	+0·3
November	+0·2	+0·2	+0·2	+0·2	+0·1	0	0	−0·1	−0·3	−0·5	−0·8	−0·8	−0·8	−0·5	−0·2	+0·1	+0·1	+0·2	+0·2	+0·3	+0·3	+0·4	+0·4	+0·4	+0·3
December	+0·3	+0·2	+0·2	+0·2	+0·2	+0·1	+0·1	−0·2	−0·4	−0·5	−0·6	−0·8	−0·5	−0·2	−0·1	+0·1	+0·1	+0·2	+0·2	+0·4	+0·5	+0·4	+0·4	+0·4	+0·5
Means	+0·2	+0·3	+0·2	+0·2	+0·2	+0·1	+0·1	0	−0·1	−0·2	−0·5	−0·8	−0·8	−0·6	−0·3	0	+0·1	+0·3	+0·3	+0·4	+0·4	+0·4	+0·4	+0·4	+0·4
Summer.																									
April	+0·3	+0·3	+0·3	+0·3	+0·1	+0·2	+0·3	+0·6	+0·7	+0·2	−0·5	−1·0	−1·3	−1·2	−0·9	−0·4	−0·2	+0·1	+0·3	+0·4	+0·5	+0·4	+0·4	+0·4	+0·3
May	+0·2	+0·2	+0·2	+0·1	+0·3	+0·2	+0·3	+0·5	+0·5	+0·1	−0·6	−1·2	−1·4	−1·3	−0·9	−0·5	−0·1	+0·3	+0·3	+0·3	+0·3	+0·4	+0·4	+0·3	+0·3
June	+0·2	+0·2	+0·2	+0·2	+0·2	+0·3	+0·5	+0·4	+0·3	0	−0·6	−1·0	−1·1	−1·1	−0·8	−0·5	0	+0·3	+0·5	+0·4	+0·5	+0·4	+0·4	+0·4	+0·4
July	+0·2	+0·1	+0·1	+0·1	+0·1	+0·2	+0·3	+0·2	+0·1	−0·2	−0·6	−0·8	−1·0	−1·0	−0·8	−0·5	−0·1	+0·3	+0·5	+0·5	+0·5	+0·5	+0·5	+0·5	+0·4
August	+0·1	+0·1	+0·1	0	+0·1	+0·1	+0·3	+0·5	+0·5	+0·3	−0·2	−0·8	−0·9	−0·9	−0·6	−0·4	−0·1	+0·1	+0·3	+0·2	+0·3	+0·3	+0·3	+0·2	+0·2
September	0	0	0	0	−0·1	−0·1	+0·1	+0·4	+0·5	+0·4	+0·1	−0·5	−0·9	−0·9	−0·7	−0·3	+0·1	+0·2	+0·2	+0·3	+0·4	+0·3	+0·2	+0·1	+0·1
Means	+0·2	+0·1	+0·1	+0·1	+0·1	+0·1	+0·3	+0·4	+0·4	+0·1	−0·4	−0·9	−1·1	−1·1	−0·8	−0·4	−0·1	+0·2	+0·3	+0·3	+0·4	+0·4	+0·4	+0·3	+0·3

NOTE.—When the sign is + the Dip is greater, and when − it is less than the mean.

E.—Tables of results at Barrackpore.

Hourly Means of the Declination as determined at Barrackpore from all available days in 1913.

Hours.	Mid.	1	2	3	4	5	6	7	8	9	10	11	Noon.	13	14	15	16	17	18	19	20	21	22	23	Mid.	Means.
	E. 0° +												Winter.													
Months.	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′
January .	40·6	40·6	40·4	40·3	40·3	40·2	40·0	39·9	40·8	41·8	41·7	40·5	39·8	39·8	40·0	40·4	40·9	41·1	41·0	40·8	40·9	40·8	40·7	40·7	40·6	40·6
February .	40·3	40·3	40·3	40·2	40·1	40·0	39·7	39·6	40·1	40·8	41·2	41·0	40·5	40·3	40·3	40·3	40·3	40·2	40·3	40·2	40·3	40·2	40·2	40·4	40·3	40·3
March .	39·9	39·8	39·8	39·7	39·6	39·5	39·5	40·1	41·0	41·4	41·3	40·2	38·9	38·4	38·8	39·5	39·9	40·0	39·8	39·7	39·7	39·6	39·7	39·8	39·8	39·8
October .	36·2	36·3	36·3	36·3	36·2	36·1	36·1	36·9	37·7	37·4	36·4	35·1	34·6	35·0	35·7	36·5	36·8	36·5	36·2	36·2	36·1	36·1	36·1	36·2	36·2	36·2
November .	36·1	36·1	36·0	35·8	35·7	35·5	35·4	35·4	36·0	36·3	36·2	35·5	35·5	36·0	36·2	36·1	36·1	36·0	36·0	36·0	36·0	35·9	35·9	36·1	36·0	35·9
December .	35·7	35·7	35·6	35·4	35·2	35·0	34·8	34·4	34·7	35·3	35·6	35·4	35·3	35·7	36·2	36·3	36·1	35·9	35·8	35·7	35·6	35·6	35·6	35·6	35·6	35·5
Means .	38·1	38·1	38·1	38·0	37·9	37·7	37·6	37·7	38·4	38·8	38·7	38·0	37·4	37·5	37·9	38·2	38·4	38·3	38·2	38·1	38·1	38·0	38·0	38·1	38·1	38·1
													Summer.													
April .	39·6	39·6	39·5	39·4	39·3	39·2	39·9	41·0	41·4	41·0	40·0	38·5	37·5	37·2	37·6	38·6	39·4	39·8	39·4	39·2	39·2	39·2	39·3	39·3	39·5	39·3
May .	39·1	39·2	39·3	39·3	39·3	39·4	40·4	41·2	41·1	39·8	38·1	36·6	35·9	36·1	37·1	38·0	38·9	39·3	39·1	38·6	38·5	38·4	38·7	38·9	39·1	38·8
June	38·4	38·5	38·7	38·7	38·9	39·1	40·4	41·0	40·8	39·7	38·3	36·8	35·9	36·1	36·5	37·0	37·9	38·5	38·3	37·9	37·8	37·9	38·1	38·2	38·4	38·3
July .	37·7	37·9	38·0	38·1	38·1	38·2	39·4	40·3	40·2	39·4	38·2	36·8	35·9	35·8	36·0	36·5	37·2	37·6	37·7	37·3	37·3	37·3	37·4	37·6	37·7	37·7
August	37·2	37·3	37·4	37·5	37·7	37·8	38·9	39·9	39·8	38·6	36·9	35·7	35·0	35·0	35·5	36·4	37·3	37·6	37·3	37·0	36·9	37·0	37·0	37·1	37·2	37·2
September .	36·8	37·0	37·0	37·0	37·0	37·0	37·6	38·7	39·0	38·2	36·8	35·3	34·3	34·4	35·1	36·3	37·2	37·3	36·8	36·7	36·6	36·6	36·6	36·7	36·8	36·8
Means .	38·1	38·3	38·3	38·3	38·4	38·5	39·4	40·4	40·4	39·5	38·1	36·6	35·8	35·8	36·3	37·1	38·0	38·4	38·1	37·8	37·7	37·7	37·9	38·0	38·1	38·0

Diurnal Inequality of the Declination at Barrackpore as deduced from the preceding Table.

Hours.	Mid.	1	2	3	4	5	6	7	8	9	10	11	Noon.	13	14	15	16	17	18	19	20	21	22	23	Mid.
Winter.																									
1913 Months.	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′
January	0	0	−0·2	−0·3	−0·3	−0·4	−0·6	−0·7	+0·2	+1·2	+1·1	−0·1	−0·8	−0·8	−0·6	−0·2	+0·3	+0·5	+0·4	+0·2	+0·3	+0·2	+0·1	+0·1	0
February	0	0	0	−0·1	−0·2	−0·3	−0·6	−0·7	−0·2	+0·5	+0·9	+0·7	+0·2	0	0	0	0	−0·1	0	−0·1	0	−0·1	−0·1	+0·1	0
March	+0·1	0	0	−0·1	−0·2	−0·3	−0·3	+0·3	+1·2	+1·6	+1·5	+0·4	−0·9	−1·4	−1·0	−0·3	+0·1	+0·2	0	−0·1	−0·1	−0·2	−0·1	0	0
October	0	+0·1	+0·1	+0·1	0	−0·1	−0·1	+0·7	+1·5	+1·2	+0·2	−1·1	−1·6	−1·2	−0·5	+0·3	+0·6	+0·3	0	0	−0·1	−0·1	−0·1	0	0
November	+0·2	+0·2	+0·1	−0·1	−0·2	−0·4	−0·5	−0·5	+0·1	+0·4	+0·3	−0·4	−0·4	+0·1	+0·3	+0·2	+0·2	+0·1	+0·1	+0·1	+0·1	0	0	+0·2	+0·1
December	+0·2	+0·2	+0·1	−0·1	−0·3	−0·5	−0·7	−1·1	−0·8	−0·2	+0·1	−0·1	−0·2	+0·2	+0·7	+0·8	+0·6	+0·4	+0·3	+0·2	+0·1	+0·1	+0·1	+0·1	+0·1
Means	0	0	0	−0·1	−0·2	−0·4	−0·5	−0·4	+0·3	+0·7	+0·6	−0·1	−0·7	−0·6	−0·2	+0·1	+0·3	+0·2	+0·1	0	0	−0·1	−0·1	0	0
Summer.																									
April	+0·3	+0·3	+0·2	+0·1	0	−0·1	+0·6	+1·7	+2·1	+1·7	+0·7	−0·8	−1·8	−2·1	−1·7	−0·7	+0·1	+0·5	+0·1	−0·1	−0·1	−0·1	0	0	+0·2
May	+0·3	+0·4	+0·5	+0·5	+0·5	+0·6	+1·6	+2·4	+2·3	+1·0	−0·7	−2·2	−2·9	−2·7	−1·7	−0·8	+0·1	+0·5	+0·3	−0·2	−0·3	−0·4	−0·1	+0·1	+0·3
June	+0·1	+0·2	+0·4	+0·4	+0·6	+0·8	+2·1	+2·7	+2·5	+1·4	0	−1·5	−2·4	−2·2	−1·8	−1·3	−0·4	+0·2	0	−0·4	−0·5	−0·4	−0·2	−0·1	+0·1
July	0	+0·2	+0·3	+0·4	+0·4	+0·5	+1·7	+2·6	+2·5	+1·7	+0·5	−0·9	−1·8	−1·9	−1·7	−1·2	−0·5	−0·1	0	−0·4	−0·4	−0·4	−0·3	−0·1	0
August	0	+0·1	+0·2	+0·3	+0·5	+0·6	+1·7	+2·7	+2·6	+1·4	−0·3	−1·5	−2·2	−2·2	−1·7	−0·8	+0·1	+0·4	+0·1	−0·2	−0·3	−0·2	−0·2	−0·1	0
September	0	+0·2	+0·2	+0·2	+0·2	+0·2	+0·8	+1·9	+2·2	+1·4	0	−1·5	−2·5	−2·4	−1·7	−0·5	+0·4	+0·5	0	−0·1	−0·2	−0·2	−0·2	−0·1	0
Means	+0·1	+0·3	+0·3	+0·3	+0·4	+0·5	+1·4	+2·4	+2·4	+1·5	+0·1	−1·4	−2·2	−2·2	−1·7	−0·9	0	+0·4	+0·1	−0·2	−0·3	−0·3	−0·1	0	+0·1

NOTE.—When the sign is + the magnet points to the East, and when − to the West of the mean position.

Hourly Means of Horizontal Force in C. G. S. Units (Corrected for temperature) at Barrackpore from all available days in 1913.

·37000 C. G. S. +

Hours.	Mid.	1	2	3	4	5	6	7	8	9	10	11	Noon.	13	14	15	16	17	18	19	20	21	22	23	Mid.	Means.
													Winter.													
Months.	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ
January .	377	378	379	380	381	382	384	387	393	394	394	397	397	397	391	387	385	381	378	376	375	375	377	377	377	384
February .	377	380	381	381	381	382	384	387	393	398	405	408	409	405	397	391	385	381	379	377	377	376	377	377	377	387
March .	378	381	380	381	381	382	383	384	389	397	406	412	413	409	402	394	387	384	382	379	378	377	377	376	378	383
October .	383	384	384	386	388	389	390	390	392	395	401	407	409	403	395	388	384	383	382	381	379	381	381	382	383	389
November .	385	386	386	388	390	392	394	399	407	412	415	418	415	408	400	395	391	390	388	385	386	384	383	383	386	395
December .	388	391	391	392	394	396	399	401	412	418	422	421	414	410	404	400	397	395	392	390	388	388	388	389	389	399
Means .	381	383	384	385	386	387	389	392	398	402	407	411	410	405	398	393	388	386	384	381	381	380	381	381	382	391
													Summer.													
April .	366	369	367	368	369	370	371	370	372	382	392	398	398	395	392	385	379	374	371	369	367	366	368	369	369	376
May .	373	373	374	374	374	375	376	377	377	382	391	399	402	400	395	387	380	376	373	374	372	372	372	373	373	380
June .	381	384	383	383	384	385	386	388	390	393	401	406	408	407	402	395	388	383	379	379	379	380	381	381	382	389
July .	382	383	383	384	384	385	386	388	390	393	399	403	407	407	404	398	391	385	381	379	379	379	381	381	382	389
August .	391	392	392	393	394	393	394	393	390	395	401	407	411	411	408	405	401	396	391	391	390	390	390	390	392	396
September .	384	385	385	386	387	387	388	385	382	384	390	394	401	403	402	397	390	383	381	381	381	381	381	383	384	388
Means .	380	381	381	381	382	383	384	384	384	388	396	401	405	404	401	395	388	383	379	379	378	378	379	380	380	386

L 2

Diurnal Inequality of the Horizontal Force at Barrackpore as deduced from the preceding Table.

Hours.	Mid.	1	2	3	4	5	6	7	8	9	10	11	Noon.	13	14	15	16	17	18	19	20	21	22	23	Mid.
													Winter.												
1913 Months.	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ
January	−7	−6	−5	−4	−3	−2	0	+3	+9	+10	+10	+13	+13	+13	+7	+3	+1	−3	−6	−8	−9	−9	−7	−7	−7
February	−10	−7	−6	−6	−6	−5	−3	0	+6	+11	+18	+21	+22	+18	+10	+4	−2	−6	−8	−10	−10	−11	−10	−10	−10
March	−10	−7	−8	−7	−7	−6	−5	−4	+1	+9	+18	+24	+25	+21	+14	+6	−1	−4	−6	−9	−10	−11	−11	−10	−10
October	−6	−5	−5	−3	−1	0	+1	+1	+3	+6	+12	+18	+20	+14	+6	−1	−5	−6	−7	−8	−10	−8	−8	−7	−6
November	−10	−9	−9	−7	−5	−3	−1	+4	+12	+17	+20	+23	+20	+13	+5	0	−4	−5	−7	−10	−9	−11	−12	−12	−9
December	−11	−8	−8	−7	−5	−3	0	+5	+13	+19	+23	+22	+15	+11	+5	+1	−2	−4	−7	−9	−11	−11	−11	−10	−10
Means	−10	−8	−7	−6	−5	−4	−2	+1	+7	+11	+16	+20	+19	+14	+7	+2	−3	−5	−7	−10	−10	−11	−10	−10	−9
													Summer.												
April	−10	−7	−9	−8	−7	−6	−5	−6	−4	+6	+16	+22	+22	+19	+16	+9	+3	−2	−5	−7	−9	−10	−8	−7	−7
May	−7	−7	−6	−6	−6	−5	−4	−3	−3	+2	+11	+19	+22	+20	+15	+7	0	−4	−7	−6	−8	−8	−8	−7	−7
June	−8	−5	−6	−6	−5	−4	−3	−1	+1	+4	+12	+17	+19	+18	+13	+6	−1	−6	−10	−10	−10	−9	−8	−8	−7
July	−7	−6	−6	−5	−5	−4	−3	−1	+1	+4	+10	+14	+18	+18	+15	+9	+2	−4	−8	−10	−10	−10	−8	−8	−7
August	−5	−4	−4	−3	−2	−3	−2	−3	−6	−1	+5	+11	+15	+15	+12	+9	+5	0	−5	−5	−6	−6	−6	−6	−4
September	−4	−3	−3	−2	−1	−1	0	−3	−6	−4	+2	+6	+13	+15	+14	+9	+2	−5	−7	−7	−7	−7	−7	−5	−4
Means	−6	−5	−5	−5	−4	−3	−2	−2	−2	+2	+10	+15	+19	+18	+15	+9	+2	−3	−7	−7	−8	−8	−7	−6	−6

NOTE.—When the sign is + the H. F. is greater, and when — it is less than the mean.

Hourly Means of Vertical Force in C. G. S. Units (Corrected for temperature) at Barrackpore from all available days in 1913.

Hours.	Mid.	1	2	3	4	5	6	7	8	9	10	11	Noon.	13	14	15	16	17	18	19	20	21	22	23	Mid.	Means.
Winter. ·33000 C. G. S. +																										
Months.	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ
January	359	359	359	359	360	360	361	**362**	362	358	352	350	**349**	350	352	**354**	358	358	359	359	359	359	359	359	359	357
February	366	366	366	367	367	368	368	369	**369**	367	363	361	**360**	360	360	361	362	364	365	366	366	367	367	367	367	365
March	370	371	370	371	371	372	372	**373**	372	368	365	361	**360**	361	364	366	367	368	369	369	370	370	371	371	371	368
October	408	408	408	408	408	409	409	**410**	408	402	398	**396**	397	400	403	405	406	406	407	408	408	408	408	408	408	406
November	411	411	411	412	412	413	414	**414**	414	411	408	405	406	405	**404**	405	408	409	411	411	410	410	410	410	410	410
December	421	422	422	423	424	425	426	427	**428**	426	423	421	420	422	421	420	**420**	421	422	421	421	421	421	421	421	422
Means	389	390	389	390	390	391	392	**393**	392	389	385	382	**382**	383	384	385	387	388	389	389	389	389	389	389	389	388
Summer.																										
April	374	374	374	374	374	375	**376**	375	372	367	363	**360**	361	365	369	371	372	372	372	373	374	374	374	374	374	371
May	378	378	378	378	378	379	**380**	377	373	367	366	**365**	368	371	374	376	377	377	377	378	379	379	379	379	379	375
June	386	386	385	386	386	387	**388**	385	382	378	377	**376**	379	381	382	384	385	385	385	386	386	387	387	387	387	384
July	394	393	393	393	393	394	**395**	393	391	389	386	**385**	386	388	389	389	391	392	393	393	393	394	394	394	394	391
August	400	400	400	400	400	400	**402**	399	396	391	**391**	391	393	395	396	397	398	398	398	399	400	400	401	400	400	398
September	404	404	404	404	404	404	**406**	404	402	398	395	**392**	393	396	400	401	402	401	402	403	404	404	404	404	404	401
Means	389	389	389	389	389	390	**391**	389	386	382	380	**378**	380	383	385	386	388	388	388	389	389	390	390	390	390	387

Diurnal Inequality of the Vertical Force at Barrackpore as deduced from the preceding Table.

Hours.	Mid.	1	2	3	4	5	6	7	8	9	10	11	Noon.	13	14	15	16	17	18	19	20	21	22	23	Mid.
Winter.																									
1913 Months.	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ		γ	γ	γ	γ	γ	γ	γ	γ	γ
January	+2	+2	+2	+2	+3	+3	+4	+5	+5	+1	−5	−7	−8	−7	−5	−3	+1	+1	+2	+2	+2	+2	+2	+2	+2
February	+1	+1	+1	+2	+2	+3	+3	+4	+4	+2	−2	−4	−5	−5	−5	−4	−3	−1	0	+1	+1	+2	+2	+2	+2
March	+2	+3	+2	+3	+3	+4	+4	+5	+4	0	−3	−7	−8	−7	−4	−2	−1	0	+1	+1	+2	+2	+3	+3	+3
October	+2	+2	+2	+2	+2	+3	+3	+4	+2	−4	−8	−10	−9	−6	−3	−1	0	0	+1	+2	+2	+2	+2	+2	+2
November	+1	+1	+1	+2	+2	+3	+4	+4	+4	+1	−2	−5	−4	−5	−6	−5	−2	−1	+1	+1	0	0	0	0	0
December	−1	0	0	+1	+2	+3	+4	+5	+6	+4	+1	−1	−2	0	−1	−2	−2	−1	0	−1	−1	−1	−1	−1	−1
Means	+1	+2	+1	+2	+2	+3	+4	+5	+4	+1	−3	−6	−6	−5	−4	−3	−1	0	+1	+1	+1	+1	+1	+1	+1
Summer.																									
April	+3	+3	+3	+3	+3	+4	+5	+4	+1	−4	−8	−11	−10	−6	−2	0	+1	+1	+1	+2	+3	+3	+3	+3	+3
May	+3	+3	+3	+3	+3	+4	+5	+2	−2	−8	−9	−10	−7	−4	−1	+1	+2	+2	+2	+3	+4	+4	+4	+4	+4
June	+2	+2	+1	+2	+2	+3	+4	+1	−2	−6	−7	−8	−5	−3	−2	0	+1	+1	+1	+2	+2	+3	+3	+3	+3
July	+3	+2	+2	+2	+2	+3	+4	+2	0	−2	−5	−6	−5	−3	−2	−2	0	+1	+2	+2	+2	+3	+3	+3	+3
August	+2	+2	+2	+2	+2	+2	+4	+1	−2	−7	−7	−7	−5	−3	−2	−1	0	0	0	+1	+2	+2	+3	+2	+2
September	+3	+3	+3	+3	+3	+3	+5	+3	+1	−3	−6	−9	−8	−5	−1	0	+1	0	+1	+2	+3	+3	+3	+3	+3
Means	+2	+2	+2	+2	+2	+3	+4	+2	−1	−5	−7	−9	−7	−4	−2	−1	+1	+1	+1	+2	+2	+3	+3	+3	+3

NOTE.—When the sign is + the V. F. is greater, and when – it is less than the mean.

Hourly Means of the Dip as determined at Barrackpore from all available days in 1913.

N 30° +

Hours.	Mid.	1	2	3	4	5	6	7	8	9	10	11	Noon.	13	14	15	16	17	18	19	20	21	22	23	Mid.	Means.
Winter.																										
Months.	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′
January .	53·3	53·2	53·2	53·2	53·2	53·2	53·1	53·1	52·8	52·5	52·1	51·9	**51·8**	51·9	52·2	52·6	52·9	53·0	53·2	53·3	**53·4**	53·4	53·3	53·3	53·3	52·9
February .	53·8	53·6	53·6	53·7	53·7	53·7	53·6	53·6	53·3	53·0	52·4	52·2	**52·0**	52·2	52·5	52·8	53·2	53·5	53·6	53·8	53·8	**53·9**	53·9	53·9	53·9	53·3
March .	54·0	54·0	53·9	54·0	54·0	54·0	53·9	53·9	53·7	53·1	52·5	52·0	**51·9**	52·1	52·6	53·1	53·4	53·6	53·8	53·9	54·0	54·1	**54·1**	54·1	54·1	53·5
October .	56·4	56·3	56·3	56·2	56·2	56·2	56·1	56·2	56·0	55·5	55·0	54·6	**54·5**	55·0	55·6	55·9	56·2	56·2	56·3	56·4	**56·5**	56·4	56·4	56·4	56·4	56·0
November .	56·5	56·4	56·4	56·4	56·3	56·3	56·3	56·1	55·8	55·4	55·0	**54·7**	54·9	55·1	55·4	55·7	56·0	56·1	56·4	56·5	56·4	56·4	**56·5**	56·5	56·4	56·0
December .	57·1	57·0	57·0	57·0	57·0	57·0	56·9	56·8	56·5	56·2	55·8	**55·7**	55·9	56·2	56·4	56·5	56·6	56·8	56·9	57·0	**57·1**	57·1	57·1	57·0	57·0	56·7
Means .	55·2	55·1	55·1	55·1	55·1	55·1	55·0	55·0	54·7	54·3	53·8	53·5	**53·5**	53·8	54·1	54·4	54·7	54·9	55·0	55·2	55·2	**55·2**	55·2	55·2	55·2	54·7
Summer.																										
April .	54·7	54·6	54·7	54·7	54·6	54·7	54·7	54·7	54·3	53·6	52·9	**52·5**	52·6	53·0	53·4	53·8	54·1	54·3	54·4	54·5	54·7	54·7	54·7	54·6	54·6	54·1
May .	54·7	54·7	54·7	54·7	54·7	54·7	54·8	54·5	54·2	53·6	53·2	**52·8**	52·9	53·2	53·6	54·0	54·4	54·5	54·7	54·7	**54·8**	54·8	54·8	54·8	54·8	54·3
June .	55·0	54·8	54·8	54·9	54·8	54·9	54·9	54·6	54·3	53·9	53·5	**53·3**	53·4	53·6	53·9	54·3	54·6	54·8	55·0	55·0	55·0	**55·1**	55·0	55·0	55·0	54·5
July .	55·5	55·4	55·4	55·3	55·3	55·3	55·4	55·1	54·9	54·7	54·2	54·0	**53·9**	54·1	54·2	54·4	54·9	55·2	55·4	55·5	55·5	**55·6**	55·5	55·5	55·5	55·0
August .	55·5	55·5	55·5	55·4	55·4	55·4	55·5	55·4	55·2	54·7	54·5	54·2	**54·2**	54·3	54·5	54·7	55·0	55·1	55·4	55·4	55·5	55·5	**55·6**	55·5	55·5	55·1
September .	56·0	56·0	56·0	56·0	55·9	55·9	56·0	56·0	56·0	55·6	55·2	54·8	**54·6**	54·7	55·1	55·3	55·7	55·9	56·0	56·1	**56·2**	56·2	56·2	56·1	56·0	55·7
Means .	55·2	55·2	55·2	55·2	55·1	55·2	55·2	55·1	54·8	54·4	53·9	**53·6**	53·6	53·8	54·1	54·4	54·8	55·0	55·2	55·2	55·3	**55·3**	55·3	55·3	55·2	54·8

Diurnal Inequality of the Dip at Barrackpore as deduced from the preceding Table.

Hours.	Mid.	1	2	3	4	5	6	7	8	9	10	11	Noon.	13	14	15	16	17	18	19	20	21	22	23	Mid.
Winter.																									
1913 Months.	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′
January	+0·4	+0·3	+0·3	+0·3	+0·3	+0·3	+0·2	+0·2	−0·1	−0·4	−0·8	−1·0	−1·1	−1·0	−0·7	−0·3	0	+0·1	+0·3	+0·4	+0·5	+0·5	+0·4	+0·4	+0·4
February	+0·5	+0·3	+0·3	+0·4	+0·4	+0·4	+0·3	+0·3	0	−0·3	−0·9	−1·1	−1·3	−1·1	−0·8	−0·5	−0·1	+0·2	+0·3	+0·5	+0·5	+0·6	+0·6	+0·6	+0·6
March	+0·5	+0·5	+0·4	+0·5	+0·5	+0·5	+0·4	+0·4	+0·2	−0·4	−1·0	−1·5	−1·6	−1·4	−0·9	−0·4	−0·1	+0·1	+0·3	+0·4	+0·5	+0·6	+0·6	+0·6	+0·6
October	+0·4	+0·3	+0·3	+0·2	+0·2	+0·2	+0·1	+0·2	0	−0·5	−1·0	−1·4	−1·5	−1·0	−0·4	−0·1	+0·2	+0·2	+0·3	+0·4	+0·5	+0·4	+0·4	+0·4	+0·4
November	+0·5	+0·4	+0·4	+0·4	+0·3	+0·3	+0·3	+0·1	−0·2	−0·6	−1·0	−1·3	−1·1	−0·9	−0·6	−0·3	0	+0·1	+0·4	+0·5	+0·4	+0·4	+0·5	+0·5	+0·4
December	+0·4	+0·3	+0·3	+0·3	+0·3	+0·3	+0·2	+0·1	−0·2	−0·5	−0·9	−1·0	−0·8	−0·5	−0·3	−0·2	−0·1	+0·1	+0·2	+0·3	+0·4	+0·4	+0·4	+0·3	+0·3
Means	+0·5	+0·4	+0·4	+0·4	+0·4	+0·4	+0·3	+0·3	0	−0·4	−0·9	−1·2	−1·2	−0·9	−0·6	−0·3	0	+0·2	+0·3	+0·5	+0·5	+0·5	+0·5	+0·5	+0·5
Summer.																									
April	+0·6	+0·5	+0·6	+0·6	+0·5	+0·6	+0·6	0·6	+0·2	−0·5	−1·2	−1·6	−1·5	−1·1	−0·7	−0·3	0	+0·2	+0·3	+0·4	+0·6	+0·6	+0·6	+0·5	+0·5
May	+0·4	+0·4	+0·4	+0·4	+0·4	+0·4	+0·5	+0·2	−0·1	−0·7	−1·1	−1·5	−1·4	−1·1	−0·7	−0·3	+0·1	+0·2	+0·4	+0·4	+0·5	+0·5	+0·5	+0·5	+0·5
June	+0·5	+0·3	+0·3	+0·4	+0·3	+0·4	+0·4	+0·1	−0·2	−0·6	−1·0	−1·2	−1·1	−0·9	−0·6	−0·2	+0·1	+0·3	+0·5	+0·5	+0·5	+0·6	+0·5	+0·5	+0·5
July	+0·5	+0·4	+0·4	+0·3	+0·3	+0·3	+0·4	+0·1	−0·1	−0·3	−0·8	−1·0	−1·1	−0·9	−0·8	−0·6	−0·1	+0·2	+0·4	+0·5	+0·5	+0·6	+0·5	+0·5	+0·5
August	+0·4	+0·4	+0·4	+0·3	+0·3	+0·3	+0·4	+0·3	+0·1	−0·4	−0·6	−0·9	−0·9	−0·8	−0·6	−0·4	−0·1	0	+0·3	+0·3	+0·4	+0·4	+0·5	+0·4	+0·4
September	+0·3	+0·3	+0·3	+0·3	+0·2	+0·2	+0·3	+0·3	+0·3	−0·1	−0·5	−0·9	−1·1	−1·0	−0·6	−0·4	0	+0·2	+0·3	+0·4	+0·5	+0·5	+0·5	+0·4	+0·3
Means	+0·4	+0·4	+0·4	+0·4	+0·3	+0·4	+0·4	+0·3	0	−0·4	−0·9	−1·2	−1·2	−1·0	−0·7	−0·4	0	+0·2	+0·4	+0·4	+0·5	+0·5	+0·5	+0·5	+0·4

NOTE.—When the sign is + the Dip is more, and when − it is less than the mean.

F.—*Tables of results at Toungoo.*

Hourly Means of the Declination as determined at Toungoo from all available days in 1913.

Hours.	Mid.	1	2	3	4	5	6	7	8	9	10	11	Noon.	13	14	15	16	17	18	19	20	21	22	23	Mid.	Means.
E. 0° +													Winter.													
Months.	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′
January .	10·1	10·0	10·0	9·9	9·9	9·8	9·6	9·3	10·0	11·0	11·1	10·2	9·6	9·6	9·6	9·9	10·4	10·6	10·4	10·4	10·2	10·2	10·1	10·1	10·1	10·1
February .	9·8	9·8	9·8	9·6	9·5	9·3	9·1	8·9	9·3	9·9	10·3	10·3	10·1	10·0	9·8	9·7	9·7	9·8	9·6	9·9	9·8	9·8	9·7	9·7	9·8	9·7
March .	9·1	9·1	9·1	9·1	9·0	8·9	8·8	9·3	10·0	10·4	10·4	9·8	8·8	8·3	8·3	8·8	9·3	9·4	9·1	9·1	9·0	9·1	9·0	9·1	9·1	9·2
October .	6·4	6·3	6·4	6·4	6·3	6·2	6·2	6·9	7·5	7·3	6·5	5·7	5·4	5·5	6·0	6·6	7·1	6·7	6·4	6·4	6·3	6·3	6·3	6·3	6·3	6·4
November .	5·9	6·0	5·9	5·8	5·7	5·5	5·4	5·4	5·9	6·2	6·2	5·9	5·9	6·2	6·2	6·2	6·3	6·3	6·0	6·0	6·0	5·9	5·8	5·9	5·9	5·9
December .	5·7	5·8	5·7	5·5	5·4	5·3	5·1	4·7	4·9	5·3	5·8	6·0	5·9	6·2	6·5	6·4	6·2	6·1	6·0	5·9	5·7	5·7	5·6	5·7	5·7	5·7
Means .	7·8	7·8	7·8	7·7	7·6	7·5	7·4	7·4	7·9	8·4	8·4	8·0	7·6	7·6	7·7	7·9	8·2	8·1	8·0	8·0	7·8	7·8	7·8	7·8	7·8	7·8
													Summer.													
April .	8·8	8·9	9·0	8·9	8·8	8·7	9·0	9·9	10·3	10·0	9·3	8·3	7·3	6·9	7·2	7·8	8·5	9·0	8·8	8·6	8·3	8·4	8·5	8·6	8·8	8·7
May .	8·2	8·5	8·5	8·5	8·5	8·6	9·5	10·3	10·3	9·3	8·0	6·7	6·1	6·1	6·7	7·5	8·3	8·7	8·4	8·0	7·9	7·9	8·0	8·0	8·2	8·2
June .	7·9	8·0	8·1	8·2	8·3	8·7	9·7	10·4	10·3	9·3	8·1	7·2	6·5	6·4	6·6	7·0	7·8	8·1	8·0	7·6	7·6	7·6	7·7	7·8	7·9	8·0
July .	7·3	7·4	7·6	7·6	7·7	7·8	8·8	9·5	9·6	9·0	8·0	7·1	6·3	6·2	6·2	6·4	6·9	7·3	7·3	7·1	7·0	7·0	7·1	7·1	7·3	7·5
August .	6·8	6·9	7·0	7·1	7·1	7·3	8·3	9·2	9·1	8·1	6·8	5·9	5·3	5·2	5·5	6·1	6·8	7·2	6·9	6·7	6·3	6·6	6·6	6·7	6·8	6·9
September .	6·9	7·0	7·1	7·1	7·1	7·1	7·8	8·7	8·8	8·3	7·2	5·9	5·2	5·1	5·5	6·5	7·3	7·4	6·9	6·8	6·8	6·8	6·7	6·8	6·9	6·9
Means .	7·7	7·8	7·9	7·9	7·9	8·0	8·9	9·7	9·7	9·0	7·9	6·9	6·1	6·0	6·3	6·9	7·6	8·0	7·7	7·5	7·4	7·4	7·4	7·5	7·7	7·7

Diurnal Inequality of the Declination at Toungoo as deduced from the preceding Table.

Hours.	Mid.	1	2	3	4	5	6	7	8	9	10	11	Noon.	13	14	15	16	17	18	19	20	21	22	23	Mid.
Winter.																									
1913 Months.	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′
January . .	0·0	-0·1	-0·1	-0·2	-0·2	-0·3	-0·5	-0·8	-0·1	+0·9	+1·0	+0·1	-0·5	-0·5	-0·5	-0·2	+0·3	+0·5	+0·3	+0·3	+0·1	+0·1	0·0	0·0	0·0
February . .	+0·1	+0·1	+0·1	-0·1	-0·2	-0·4	-0·6	-0·8	-0·4	+0·2	+0·6	+0·6	+0·4	+0·3	+0·1	0·0	0·0	+0·1	+0·1	+0·2	+0·1	+0·1	0·0	0·0	+0·1
March . . .	-0·1	-0·1	-0·1	-0·1	-0·2	-0·3	-0·4	+0·1	+0·8	+1·2	+1·2	+0·6	-0·4	-0·9	-0·9	-0·4	+0·1	+0·2	-0·1	-0·1	-0·2	-0·1	-0·2	-0·1	-0·1
October . .	0·0	-0·1	0·0	0·0	-0·1	-0·2	-0·2	+0·5	+1·1	+0·9	+0·1	-0·7	-1·0	-0·9	-0·4	+0·2	+0·7	+0·3	0·0	0·0	-0·1	-0·1	-0·1	-0·1	-0·1
November . .	0·0	+0·1	0·0	-0·1	-0·2	-0·4	-0·5	-0·5	0·0	+0·3	+0·3	0·0	0·0	+0·3	+0·3	+0·3	+0·4	+0·3	+0·1	+0·1	+0·1	0·0	-0·1	0·0	0·0
December . .	0·0	+0·1	0·0	-0·2	-0·3	-0·4	-0·6	-1·0	-0·8	-0·4	+0·1	+0·3	+0·2	+0·5	+0·8	+0·7	+0·5	+0·4	+0·3	+0·2	0·0	0·0	-0·1	0·0	0·0
Means . .	0·0	0·0	0·0	-0·1	-0·2	-0·3	-0·4	-0·4	+0·1	+0·6	+0·6	+0·2	-0·2	-0·2	-0·1	+0·1	+0·4	+0·3	+0·2	+0·2	0·0	0·0	0·0	0·0	0·0
Summer.																									
April . . .	+0·1	+0·2	+0·3	+0·2	+0·1	0·0	+0·3	+1·2	+1·6	+1·3	+0·6	-0·4	-1·4	-1·8	-1·5	-0·9	-0·2	+0·3	+0·1	-0·1	-0·4	-0·3	-0·2	-0·1	+0·1
May . . .	0·0	+0·3	+0·3	+0·3	+0·3	+0·4	+1·3	+2·1	+2·1	+1·1	-0·2	-1·5	-2·1	-2·1	-1·5	-0·7	+0·1	+0·5	+0·2	-0·2	-0·3	-0·3	-0·2	-0·2	0·0
June . . .	-0·1	0·0	+0·1	+0·2	+0·3	+0·7	+1·7	+2·4	+2·3	+1·3	+0·1	-0·8	-1·5	-1·6	-1·4	-1·0	-0·2	+0·1	0·0	-0·4	-0·4	-0·4	-0·3	-0·2	-0·1
July . . .	-0·2	-0·1	+0·1	+0·1	+0·2	+0·3	+1·3	+2·0	+2·1	+1·5	+0·5	-0·4	-1·2	-1·3	-1·3	-1·1	-0·6	-0·2	-0·2	-0·4	-0·5	-0·5	-0·4	-0·4	-0·2
August . .	-0·1	0·0	+0·1	+0·2	+0·2	+0·4	+1·4	+2·3	+2·2	+1·2	-0·1	-1·0	-1·6	-1·7	-1·4	-0·6	-0·1	+0·3	0·0	-0·2	-0·3	-0·3	-0·3	-0·2	-0·1
September . .	0·0	+0·1	+0·2	+0·2	+0·2	+0·2	+0·9	+1·8	+1·9	+1·4	+0·3	-1·0	-1·7	-1·8	-1·4	-0·4	+0·4	+0·5	0·0	-0·1	-0·1	-0·1	-0·2	-0·1	0·0
Means . .	-0·0	+0·1	+0·2	+0·2	+0·2	+0·3	+1·2	+2·0	+2·0	+1·3	+0·2	-0·8	-1·6	-1·7	-1·4	-0·8	-0·1	+0·3	0·0	-0·2	-0·3	-0·3	-0·3	-0·2	0·0

NOTE.—When the sign is + the magnet points to the East, and when - to the West of the mean position.

Hourly Means of Horizontal Force in C. G. S. Units (Corrected for temperature) at Toungoo from all available days in 1913.

·38000 C. G. S.+

Hours.	Mid	1	2	3	4	5	6	7	8	9	10	11	Noon.	13	14	15	16	17	18	19	20	21	22	23	Mid.	Means.
Winter.																										
Months.	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ
January	913	914	914	916	916	916	919	923	928	932	936	936	937	933	927	920	916	914	913	912	910	911	912	913	913	920
February	919	921	923	924	924	924	926	929	933	942	948	953	954	949	941	933	929	924	921	919	918	919	919	921	920	930
March	930	930	931	930	932	933	932	934	940	951	961	969	967	961	952	942	937	932	931	930	928	926	927	928	928	939
October	973	975	973	976	977	978	978	977	981	989	999	1004	1001	991	982	976	971	971	971	971	971	971	972	973	973	979
November	981	983	983	984	985	987	988	993	999	1007	1012	1016	1013	1005	998	991	986	984	983	983	983	983	982	982	982	991
December	986	986	987	987	988	989	992	998	1004	1010	1014	1013	1009	1003	997	992	990	988	987	986	986	985	985	987	986	994
Means	950	952	952	953	954	955	956	959	964	972	978	982	980	974	966	959	955	952	951	950	949	949	950	951	950	959
Summer.																										
April	929	931	930	930	932	932	933	933	938	951	964	968	968	962	954	947	939	934	933	931	930	929	930	931	933	940
May	948	948	948	949	950	949	949	953	957	965	973	977	979	976	969	960	951	946	945	947	946	946	946	946	948	955
June	962	963	964	963	963	964	966	968	973	981	986	990	990	987	981	973	965	960	959	960	960	960	961	962	962	969
July	970	971	972	972	972	973	974	977	981	986	993	998	1000	999	994	986	978	972	969	970	970	970	970	970	970	979
August	977	977	978	978	979	978	979	979	981	987	995	998	999	997	993	989	984	979	977	976	976	975	976	976	977	983
September	975	975	975	976	977	977	976	973	975	982	989	994	997	995	990	985	977	972	970	971	971	971	972	974	974	979
Means	960	961	961	961	962	962	963	964	968	975	983	988	989	986	980	973	966	961	959	959	959	959	959	960	961	967

Diurnal Inequality of the Horizontal Force at Toungoo as deduced from the preceding Table.

Hours.	Mid.	1	2	3	4	5	6	7	8	9	10	11	Noon.	13	14	15	16	17	18	19	20	21	22	23	Mid.
Winter.																									
1913 Months.	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ
January	−7	−6	−6	−4	−4	−4	−1	+3	+8	+12	+16	+16	+17	+13	+7	0	−4	−6	−7	−8	−10	−9	−8	−7	−7
February	−11	−9	−7	−6	−6	−6	−4	−1	+3	+12	+18	+23	+24	+19	+11	+8	−1	−6	−9	−11	−12	−11	−11	−9	−10
March	−9	−9	−8	−9	−7	−6	−7	−5	+1	+12	+22	+30	+28	+22	+13	+3	−2	−7	−8	−9	−11	−13	−12	−11	−11
October	−6	−4	−6	−3	−2	−1	−1	−2	+2	+10	+20	+25	+22	+12	+3	−3	−8	−8	−8	−8	−8	−8	−7	−6	−6
November	−10	−8	−8	−7	−6	−4	−3	+2	+8	+16	+21	+25	+22	+14	+7	0	−5	−7	−8	−9	−8	−8	−9	−9	−9
December	−8	−8	−7	−7	−6	−5	−2	+4	+10	+16	+20	+19	+15	+8	+3	−2	−4	−6	−7	−8	−8	−9	−9	−7	−8
Means	−9	−7	−7	−6	−5	−4	−3	0	+5	+13	+19	+23	+21	+15	+7	0	−4	−7	−8	−9	−10	−10	−9	−8	−9
Summer.																									
April	−11	−9	−10	−10	−8	−8	−7	−7	−2	+11	+24	+28	+28	+22	+14	+7	−1	−6	−7	−9	−10	−11	−10	−9	−7
May	−7	−7	−7	−6	−5	−6	−6	−2	+2	+10	+18	+22	+24	+21	+14	+5	−4	−9	−10	−8	−9	−9	−9	−9	−7
June	−7	−6	−5	−6	−6	−5	−3	−1	+4	+12	+17	+21	+21	+18	+12	+4	−4	−9	−10	−9	−9	−9	−8	−7	−7
July	−9	−8	−7	−7	−7	−6	−5	−2	+2	+7	+14	+19	+21	+20	+15	+7	−1	−7	−10	−9	−9	−9	−9	−9	−9
August	−6	−6	−5	−5	−4	−5	−4	−4	−2	+4	+12	+15	+16	+14	+10	+6	+1	−4	−6	−7	−7	−8	−7	−7	−6
September	−4	−4	−4	−3	−2	−2	−3	−6	−4	+3	+10	+15	+18	+16	+11	+6	−2	−7	−9	−8	−8	−8	−7	−5	−5
Means	−7	−6	−6	−6	−5	−5	−4	−3	+1	+8	+16	+21	+22	+19	+13	+6	−1	−6	−8	−8	−8	−8	−8	−7	−6

NOTE.—When the sign is + the H. F. is greater, and when − it is less than the mean.

Hourly Means of Vertical Force in C. G. S. Units (Corrected for temperature) at Toungoo from all available days in 1913.

Hours.	Mid.	1	2	3	4	5	6	7	8	9	10	11	Noon.	13	14	15	16	17	18	19	20	21	22	23	Mid.	Means.
·16000 C. G. S.+													Winter.													
Months.	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ
January .	590	590	590	590	590	591	590	590	592	590	582	576	575	580	584	589	592	591	590	591	591	591	592	592	592	588
February .	586	586	586	586	586	585	585	585	585	584	580	578	577	578	579	581	582	583	585	586	586	586	586	587	587	584
March .	592	593	593	593	592	592	592	594	591	586	582	577	576	580	585	590	591	590	591	591	592	592	592	593	593	589
October .	621	621	621	621	621	621	622	622	617	609	604	603	607	612	618	620	620	618	618	619	620	620	621	621	621	617
November .	624	624	624	624	624	624	623	623	622	619	616	614	616	617	618	619	621	622	623	623	624	624	624	624	625	622
December .	621	621	621	621	621	621	620	619	619	619	618	618	617	620	620	619	619	619	621	621	621	621	621	621	621	620
Means .	606	606	606	606	606	606	605	606	604	601	597	594	595	598	601	603	604	604	605	605	606	606	606	606	607	603
													Summer.													
April . .	598	598	598	598	598	598	600	599	593	586	581	578	580	585	591	597	599	598	595	596	596	597	597	598	598	594
May . .	604	604	604	604	604	605	608	606	599	591	587	588	593	599	604	607	608	606	603	603	603	604	604	604	604	602
June . .	611	611	611	611	611	612	615	613	608	600	597	597	599	604	608	612	614	613	611	610	611	611	611	611	611	609
July . .	613	613	613	613	613	614	617	615	611	605	601	600	601	605	608	611	613	614	613	612	613	613	613	610	610	611
August .	619	619	619	619	619	620	624	620	613	605	601	602	605	610	614	618	619	618	617	618	618	618	619	619	620	616
September .	617	617	617	617	617	617	621	619	612	604	597	595	598	606	613	617	618	615	614	615	616	616	617	617	617	613
Means .	610	610	610	610	610	611	614	612	606	599	594	593	596	602	606	610	612	611	609	609	610	610	610	610	610	608

Diurnal Inequality of the Vertical Force at Toungoo as deduced from the preceding Table.

Hours.	Mid.	1	2	3	4	5	6	7	8	9	10	11	Noon.	13	14	15	16	17	18	19	20	21	22	23	Mid.
Winter.																									
1913 Months.	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ
January . .	+2	+2	+2	+2	+2	+3	+2	+2	+4	+2	−6	−12	−13	−8	−4	+1	+4	+3	+2	+3	+3	+3	+4	+4	+4
February . .	+2	+2	+2	+2	+2	+1	+1	+1	+1	0	−4	−6	−7	−6	−5	−3	−2	−1	+1	+2	+2	+2	+2	+3	+3
March . . .	+3	+4	+4	+4	+3	+3	+3	+5	+2	−3	−7	−12	−13	−9	−4	+1	+2	+1	+2	+2	+3	+3	+3	+4	+4
October . . .	+4	+4	+4	+4	+4	+4	+5	+5	0	−8	−13	14	−10	−5	+1	+3	+3	+1	+1	+2	+3	+3	+4	+4	+4
November . .	+2	+2	+2	+2	+2	+2	+1	+1	0	−3	−6	−8	−6	−5	−4	−3	−1	0	+1	+1	+2	+2	+2	+2	+3
December . .	+1	+1	+1	+1	+1	+1	0	−1	−1	−1	−2	−2	−3	0	0	−1	−1	−1	+1	+1	+1	+1	+1	+1	+1
Means .	+3	+3	+3	+3	+3	+3	+2	+3	+1	−2	−6	−9	−8	−5	−2	0	+1	+1	+2	+2	+3	+3	+3	+3	+4
Summer.																									
April . . .	+4	+4	+4	+4	+4	+4	+6	+5	−1	−8	−13	−16	−14	−9	−3	+3	+5	+4	+1	+2	+2	+3	+3	+4	+4
May . .	+2	+2	+2	+2	+2	+3	+6	+4	−3	−11	−15	−14	−9	−3	+2	+5	+6	+4	+1	+1	+1	+2	+2	+2	+2
June . . .	+2	+2	+2	+2	+2	+3	+6	+4	−1	−9	−12	−12	−10	−5	−1	+3	+5	+4	+2	+1	+2	+2	+2	+2	+2
July . . .	+2	+2	+2	+2	+2	+3	+6	+4	0	−6	−10	−11	−10	−6	−3	0	+2	+3	+2	+1	+2	+2	+2	−1	−1
August . . .	+3	+3	+3	+3	+3	+4	+8	+4	−3	−11	−15	−14	−11	−6	−2	+2	+3	+2	+1	+2	+2	+2	+3	+3	+4
September . .	+4	+4	+4	+4	+4	+4	+8	+6	−1	−9	−16	−18	−15	−7	0	+4	+5	+2	+1	+2	+3	+3	+4	+4	+4
Means .	+2	+2	+2	+2	+2	+3	+6	+4	−2	−9	−14	−15	−12	−6	−2	+2	+4	+3	+1	+1	+2	+2	+2	+2	+2

NOTE.—When the sign is + the Vertical Force is greater, and when − it is less than the mean.

Hourly Means of the Dip as determined at Toungoo from all available days in 1913.

Hours.	Mid.	1	2	3	4	5	6	7	8	9	10	11	Noon.	13	14	15	16	17	18	19	20	31	22	23	Mid.	Means.
Winter. N. 23°+																										
Months.	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′
January	5·4	5·4	5·4	5·3	5·3	5·4	5·2	5·1	5·1	4·8	4·1	3·7	3·5	4·0	4·5	5·1	5·5	5·4	5·4	5·5	5·6	5·6	5·6	5·6	5·6	5·1
February	4·9	4·9	4·8	4·8	4·8	4·7	4·6	4·6	4·4	4·1	3·5	3·3	3·2	3·4	3·7	4·1	4·3	4·5	4·8	4·9	5·0	4·9	4·9	5·0	5·0	4·4
March	5·0	5·1	5·0	5·1	5·0	4·9	5·0	5·0	4·6	3·9	3·3	2·7	2·7	3·1	3·8	4·5	4·7	4·8	4·9	5·0	5·1	5·2	5·1	5·2	5·2	4·5
October	5·8	5·8	5·8	5·7	5·7	5·7	5·7	5·8	5·3	4·1	3·7	3·5	3·9	4·6	5·3	5·6	5·8	5·7	5·7	5·7	5·8	5·8	5·9	5·8	5·8	5·4
November	5·8	5·7	5·7	5·7	5·7	5·6	5·5	5·3	5·1	4·6	4·2	3·9	4·2	4·5	4·8	5·1	5·4	5·5	5·6	5·7	5·7	5·7	5·8	5·8	5·8	5·3
December	5·4	5·4	5·4	5·4	5·4	5·3	5·1	4·9	4·7	4·5	4·3	4·3	4·4	4·8	5·0	5·0	5·1	5·2	5·4	5·4	5·4	5·4	5·4	5·4	5·4	5·1
Means	5·4	5·4	5·4	5·3	5·3	5·3	5·2	5·1	4·9	4·4	3·9	3·6	3·7	4·1	4·5	4·9	5·1	5·2	5·3	5·4	5·4	5·4	5·5	5·5	5·5	5·0
Summer.																										
April	5·5	5·4	5·5	5·5	5·4	5·4	5·5	5·4	4·8	3·9	3·1	2·8	2·9	3·5	4·2	4·9	5·3	5·4	5·2	5·3	5·3	5·4	5·4	5·4	5·4	4·8
May	5·3	5·3	5·3	5·3	5·3	5·4	5·6	5·4	4·7	3·9	3·3	3·2	3·5	4·1	4·7	5·2	5·6	5·6	5·4	5·3	5·4	5·4	5·4	5·4	5·3	5·0
June	5·4	5·4	5·4	5·4	5·4	5·4	5·6	5·4	4·9	4·0	3·6	3·5	3·7	4·1	4·6	5·2	5·6	5·6	5·5	5·4	5·5	5·5	5·5	5·4	5·4	5·0
July	5·3	5·3	5·3	5·3	5·3	5·3	5·5	5·2	4·8	4·2	3·7	3·5	3·5	3·8	4·2	4·7	5·1	5·3	5·4	5·2	5·3	5·3	5·3	5·1	5·1	4·9
August	5·5	5·5	5·5	5·5	5·5	5·6	5·9	5·6	5·0	4·2	3·6	3·6	3·8	4·3	4·6	5·1	5·3	5·4	5·4	5·5	5·5	5·5	5·6	5·6	5·6	5·1
September	5·4	5·4	5·4	5·4	5·4	5·4	5·7	5·7	5·1	4·3	3·5	3·2	3·4	4·0	4·7	5·1	5·5	5·4	5·4	5·4	5·5	5·5	5·6	5·5	5·5	5·0
Means	5·4	5·4	5·4	5·4	5·4	5·4	5·8	5·5	4·9	4·1	3·5	3·3	3·5	4·0	4·5	5·0	5·4	5·5	5·4	5·4	5·4	5·4	5·5	5·4	5·4	5·0

Diurnal Inequality of the Dip at Toungoo as deduced from the preceding Table.

Hours.	Mid	1	2	3	4	5	6	7	8	9	10	11	Noon.	13	14	15	16	17	18	19	20	21	22	23	Mid.
Winter.																									
1913 Months.	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	
January	+0·3	+0·3	+0·3	+0·2	+0·2	+0·3	+0·1	0	0	−0·3	−1·0	−1·4	−1·6	−1·1	−0·6	0	+0·4	+0·3	+0·3	+0·4	+0·5	+0·5	+0·5	+0·5	+0·5
February	+0·5	+0·5	+0·4	+0·4	+0·4	+0·3	+0·2	+0·2	0	−0·3	−0·9	−1·1	−1·2	−1·0	−0·7	−0·3	−0·1	+0·1	+0·4	+0·5	+0·6	+0·5	+0·5	+0·6	+0·6
March	+0·5	+0·6	+0·5	+0·6	+0·5	+0·4	+0·5	+0·5	+0·1	−0·6	−1·2	−1·8	−1·8	−1·4	−0·7	0	+0·2	+0·3	+0·4	+0·5	+0·6	+0·7	+0·6	+0·7	+0·7
October	+0·4	+0·4	+0·4	+0·3	+0·3	+0·3	+0·3	+0·4	−0·1	−1·0	−1·7	−1·9	−1·5	−0·8	−0·1	+0·2	+0·4	+0·3	+0·3	+0·3	+0·4	+0·4	+0·5	+0·4	+0·4
November	+0·5	+0·4	+0·4	+0·4	+0·4	+0·3	+0·2	0	−0·2	−0·7	−1·1	−1·4	−1·1	−0·8	−0·5	−0·2	+0·1	+0·2	+0·3	+0·4	+0·4	+0·4	+0·5	+0·5	+0·5
December	+0·3	+0·3	+0·3	+0·3	+0·3	+0·2	0	−0·2	−0·4	−0·6	−0·8	−0·8	−0·7	−0·3	−0·1	−0·1	0	+0·1	+0·3	+0·3	+0·3	+0·3	+0·3	+0·3	+0·3
Means	+0·4	+0·4	+0·4	+0·3	+0·3	+0·3	+0·2	+0·1	−0·1	−0·6	−1·1	−1·4	−1·3	−0·9	−0·5	−0·1	+0·1	+0·2	+0·3	+0·4	+0·4	+0·4	+0·5	+0·5	+0·5
Summer.																									
April	+0·7	+0·6	+0·7	+0·7	+0·6	+0·6	+0·7	+0·6	0	−0·9	−1·7	−2·0	−1·9	−1·3	−0·6	+0·1	+0·5	+0·6	+0·4	+0·5	+0·5	+0·6	+0·6	+0·6	+0·6
May	+0·3	+0·3	+0·3	+0·3	+0·3	+0·4	+0·6	+0·4	−0·3	−1·1	−1·7	−1·8	−1·5	−0·9	−0·3	+0·2	+0·6	+0·6	+0·4	+0·3	+0·4	+0·4	+0·4	+0·4	+0·3
June	+0·4	+0·4	+0·4	+0·4	+0·4	+0·4	+0·6	+0·4	−0·1	−1·0	−1·4	−1·5	−1·3	−0·9	−0·4	+0·2	+0·6	+0·6	+0·5	+0·4	+0·5	+0·5	+0·5	+0·4	+0·4
July	+0·4	+0·4	+0·4	+0·4	+0·4	+0·4	+0·6	+0·3	−0·1	−0·7	−1·2	−1·4	−1·4	−1·1	−0·7	−0·2	+0·2	+0·4	+0·5	+0·3	+0·4	+0·4	+0·4	+0·2	+0·2
August	+0·4	+0·4	+0·4	+0·4	+0·4	+0·5	+0·8	+0·5	−0·1	−0·9	−1·5	−1·5	−1·3	−0·8	−0·5	0	+0·2	+0·3	+0·3	+0·4	+0·4	+0·4	+0·5	+0·5	+0·5
September	+0·4	+0·4	+0·4	+0·4	+0·4	+0·4	+0·7	+0·7	+0·1	−0·7	−1·5	−1·8	−1·6	−1·0	−0·3	+0·1	+0·5	+0·4	+0·4	+0·4	+0·5	+0·5	+0·6	+0·5	+0·5
Means	+0·4	+0·4	+0·4	+0·4	+0·4	+0·4	+0·6	+0·5	−0·1	−0·9	−1·5	−1·7	−1·5	−1·0	−0·5	0	+0·4	+0·5	+0·4	+0·4	+0·4	+0·4	+0·5	+0·4	+0·4

NOTE.—When the sign is + the Dip is more, and when — it is less than the mean.

G.—Tables of results at Kodaikānal.

Hourly Means of the Declination as determined at Kodaikānal from all available days in 1913.

W 1°+

Hours.	Mid.	1	2	3	4	5	6	7	8	9	10	11	Noon.	13	14	15	16	17	18	19	20	21	22	23	Mid.	Means.
Winter.																										
Months.	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′
January	8·8	8·8	8·9	8·9	9·0	9·0	9·3	9·5	9·3	8·6	8·3	8·8	8·9	8·8	8·5	8·4	8·3	8·3	8·4	8·4	8·5	8·6	8·7	8·7	8·8	8·7
February	9·1	9·1	9·2	9·2	9·4	9·6	9·8	10·0	9·8	9·4	9·0	8·9	9·0	8·9	8·9	8·9	8·9	9·0	9·1	9·1	9·2	9·2	9·2	9·2	9·1	9·2
March	9·8	9·8	9·8	9·8	9·9	9·9	9·9	9·8	9·5	9·4	9·3	9·5	9·9	10·1	10·0	9·5	9·3	9·3	9·6	9·7	9·8	9·8	9·8	9·8	9·8	9·7
October	12·9	12·9	12·9	13·0	13·0	13·1	12·9	12·6	12·3	12·5	13·2	13·8	13·8	13·3	13·0	12·5	12·2	12·5	12·8	12·9	13·0	13·0	13·0	13·0	12·9	12·9
November	13·1	13·1	13·2	13·3	13·5	13·7	13·9	14·1	13·8	13·6	13·7	13·8	13·6	13·2	12·8	12·8	12·9	13·1	13·0	13·1	13·1	13·1	13·2	13·1	13·1	13·3
December	13·7	13·7	13·8	13·9	14·1	14·2	14·3	14·9	14·8	14·4	14·1	13·9	13·7	13·5	13·1	12·9	13·0	13·3	13·3	13·6	13·6	13·6	13·7	13·7	13·7	13·8
Means	11·2	11·2	11·3	11·4	11·5	11·6	11·7	11·8	11·6	11·3	11·3	11·5	11·5	11·3	11·1	10·8	10·8	10·9	11·0	11·1	11·2	11·2	11·3	11·3	11·2	11·3
Summer.																										
April	9·9	9·9	9·9	9·9	10·0	10·0	9·7	8·9	8·9	9·2	9·7	10·2	10·8	11·0	10·8	10·3	9·9	9·7	9·9	10·1	10·2	10·2	10·1	10·0	9·9	10·0
May	10·5	10·4	10·3	10·3	10·3	10·1	9·6	9·0	9·2	9·9	11·0	11·9	12·4	12·3	11·5	10·8	10·4	10·2	10·4	10·8	10·9	10·9	10·8	10·7	10·5	10·6
June	10·9	10·8	10·8	10·7	10·5	10·4	9·8	9·2	9·4	10·2	11·2	12·1	12·5	12·5	12·0	11·4	10·9	10·7	10·9	11·3	11·3	11·2	11·2	11·0	10·9	11·0
July	11·3	11·2	11·1	11·0	11·0	11·0	10·5	9·9	9·8	10·4	11·2	12·1	12·6	12·7	12·4	12·0	11·6	11·3	11·4	11·7	11·9	11·8	11·7	11·5	11·3	11·4
August	11·9	11·9	11·8	11·7	11·6	11·4	10·9	10·0	10·2	11·2	12·2	13·1	13·5	13·4	12·9	12·3	11·7	11·4	11·7	12·0	12·1	12·1	12·0	12·0	11·9	11·9
September	12·1	12·2	12·2	12·2	12·3	12·2	11·6	11·0	11·0	11·7	12·6	13·5	14·1	14·1	13·4	12·7	12·0	11·9	12·2	12·4	12·5	12·6	12·5	12·4	12·2	12·4
Means	11·1	11·1	11·0	11·0	11·0	10·9	10·4	9·7	9·8	10·4	11·3	12·2	12·7	12·7	12·2	11·6	11·1	10·9	11·1	11·4	11·5	11·5	11·4	11·3	11·1	11·2

Diurnal Inequality of the Declination at Kodaikānal as deduced from the preceding Table.

Hours.	Mid.	1	2	3	4	5	6	7	8	9	10	11	Noon.	13	14	15	16	17	18	19	20	21	22	23	Mid.
Winter.																									
1913. Months.	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′
January	−0·1	−0·1	−0·2	−0·2	−0·3	−0·3	−0·6	−0·8	−0·6	+0·1	+0·4	−0·1	−0·2	−0·1	+0·2	+0·3	+0·4	+0·4	+0·3	+0·3	+0·3	+0·1	0·0	0·0	−0·1
February	+0·1	+0·1	0·0	0·0	−0·2	−0·4	−0·6	−0·8	−0·6	−0·2	+0·2	+0·3	+0·2	+0·3	+0·3	+0·3	+0·3	+0·2	+0·1	+0·1	0·0	0·0	0·0	0·0	+0·1
March	−0·1	−0·1	−0·1	−0·1	−0·2	−0·2	−0·2	−0·1	+0·2	+0·3	+0·4	+0·2	−0·2	−0·4	−0·3	+0·2	+0·4	+0·4	+0·1	0·0	−0·1	−0·1	−0·1	−0·1	−0·1
October	0·0	0·0	0·0	−0·1	−0·1	−0·2	0·0	+0·3	+0·6	+0·4	−0·3	−0·9	−0·9	−0·4	−0·1	+0·4	+0·7	+0·4	+0·1	0·0	−0·1	−0·1	−0·1	−0·1	0·0
November	+0·2	+0·2	+0·1	0·0	−0·2	−0·4	−0·6	−0·8	−0·5	−0·3	−0·4	−0·5	−0·3	+0·1	+0·5	+0·5	+0·4	+0·2	+0·3	+0·2	+0·2	+0·2	+0·1	+0·2	+0·2
December	+0·1	+0·1	0·0	−0·1	−0·3	−0·4	−0·5	−1·1	−1·0	−0·6	−0·3	−0·1	+0·1	+0·3	+0·7	+0·9	+0·8	+0·5	+0·5	+0·2	+0·2	+0·2	+0·1	+0·1	+0·1
Means	+0·1	+0·1	0·0	−0·1	−0·2	−0·3	−0·4	−0·5	−0·3	0·0	0·0	−0·2	−0·2	0·0	+0·2	+0·5	+0·5	+0·4	+0·3	+0·2	+0·1	+0·1	0·0	0·0	+0·1
Summer.																									
April	+0·1	+0·1	+0·1	+0·1	0·0	0·0	+0·3	+1·1	+1·1	+0·8	+0·3	−0·2	−0·8	−1·0	−0·8	−0·3	+0·1	+0·3	+0·1	−0·1	−0·2	−0·2	−0·1	0·0	+0·1
May	+0·1	+0·2	+0·3	+0·3	+0·3	+0·5	+1·0	+1·6	+1·4	+0·7	−0·4	−1·3	−1·8	−1·7	−0·9	−0·2	+0·2	+0·4	+0·2	−0·2	−0·3	−0·3	−0·2	−0·1	+0·1
June	+0·1	+0·2	+0·2	+0·3	+0·4	+0·6	+1·2	+1·8	+1·6	+0·8	−0·2	−1·1	−1·5	−1·5	−1·0	−0·4	+0·1	+0·3	+0·1	−0·3	−0·3	−0·2	−0·2	0·0	+0·1
July	+0·1	+0·2	+0·3	+0·4	+0·4	+0·4	+0·9	+1·5	+1·6	+1·0	+0·2	−0·7	−1·2	−1·3	−1·0	−0·6	−0·2	+0·1	0·0	−0·3	−0·5	−0·4	−0·3	−0·1	+0·1
August	0·0	0·0	+0·1	+0·2	+0·3	+0·5	+1·0	+1·9	+1·7	+0·7	−0·3	−1·2	−1·6	−1·5	−1·0	−0·4	+0·2	+0·5	+0·2	−0·1	−0·2	−0·2	−0·1	−0·1	0·0
September	+0·3	+0·2	+0·2	+0·2	+0·1	+0·2	+0·8	+1·4	+1·4	+0·7	−0·2	−1·1	−1·7	−1·7	−1·0	−0·3	+0·4	+0·5	+0·2	0·0	−0·1	−0·2	−0·1	0·0	+0·2
Means	+0·1	+0·1	+0·2	+0·2	+0·2	+0·3	+0·8	+1·5	+1·4	+0·8	−0·1	−1·0	−1·5	−1·5	−1·0	−0·4	+0·1	+0·3	+0·1	−0·2	−0·3	−0·3	−0·2	−0·1	+0·1

NOTE.—When the sign is + the magnet points to the East, and when — to the West of the mean position.

Hourly Means of Horizontal Force in C. G. S. Units (Corrected for temperature) at Kodaikānal from all available days in 1913.

Hours.	Mid.	1	2	3	4	5	6	7	8	9	10	11	Noon.	13	14	15	16	17	18	19	20	21	22	23	Mid.	Means.
·37000 C. G. S. +													Winter.													
Months.	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ
January .	541	540	543	542	542	543	545	540	559	576	592	**604**	601	587	566	549	542	541	542	**539**	539	540	540	540	541	554
February .	535	536	537	537	537	539	540	546	557	570	576	**583**	580	572	562	553	546	540	537	535	534	535	534	**533**	535	548
March .	531	530	531	532	533	533	533	536	553	575	596	**606**	598	579	558	545	538	537	536	532	530	529	529	**529**	530	547
October .	542	543	544	545	545	545	545	550	568	591	607	**609**	592	574	556	545	543	543	544	542	541	540	**540**	540	541	556
November .	547	547	547	549	548	549	552	560	573	587	**595**	593	586	577	566	560	555	552	550	549	549	547	**546**	546	547	560
December .	**548**	549	549	550	550	551	555	563	574	584	**586**	582	573	567	561	558	555	552	550	550	549	549	549	549	548	558
Means .	541	541	542	543	543	543	545	551	564	581	592	**596**	588	576	562	552	547	544	543	541	540	540	540	**540**	540	554
													Summer.													
April . .	**528**	529	529	530	531	530	530	536	561	588	605	**607**	592	571	551	536	531	532	532	530	529	529	529	530	530	546
May . .	536	537	538	538	537	537	540	544	560	581	595	**597**	590	575	555	539	**532**	533	536	535	535	533	534	536	536	549
June . .	547	546	547	548	548	548	550	557	567	580	586	**588**	583	573	558	546	539	**539**	541	542	542	542	544	545	547	554
July . .	541	545	545	546	545	545	547	551	559	572	582	**589**	588	578	565	551	540	**537**	540	541	541	541	541	543	544	553
August .	547	548	548	549	548	548	550	554	567	584	592	**596**	591	580	569	558	550	547	548	546	545	545	**545**	547	547	558
September .	543	543	544	545	545	545	544	549	568	592	608	**614**	602	581	560	546	**540**	541	545	542	540	541	541	542	543	557
Means .	541	541	542	543	542	542	544	549	564	583	595	**599**	591	576	560	546	539	**538**	540	539	539	539	539	541	541	553

Diurnal inequality of the Horizontal Force at Kodaikānal as deduced from the preceding Table.

Hours.	Mid.	1	2	3	4	5	6	7	8	9	10	11	Noon.	13	14	15	16	17	18	19	20	21	22	23	Mid.
Winter.																									
1913. Months.	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ
January . .	−13	−14	−11	−12	−12	−11	− 9	− 5	+ 5	+22	+38	+50	+47	+33	+13	− 5	−12	−13	−12	−15	−15	−14	−14	−14	−13
February . .	−13	−12	−11	−11	−11	− 9	− 8	− 2	+ 9	+22	+28	+35	+32	+24	+14	+ 5	− 2	− 8	−11	−13	−14	−13	−14	−15	−13
March . . .	−16	−17	−16	−15	−14	−14	−14	−11	+ 6	+28	+49	+59	+51	+32	+11	− 2	− 9	−10	−11	−15	−17	−18	−18	−18	−17
October . .	−14	−13	−12	−11	−11	−11	−11	− 6	+12	+25	+51	+53	+36	+18	0	−11	−13	−13	−12	−14	−15	−16	−16	−16	−15
November . .	−13	−13	−13	−11	−12	−11	− 8	0	+13	+27	+3	+33	+26	+17	+ 6	0	− 5	− 8	−10	−11	−11	−13	−14	−14	−13
December . .	− 10	−9	− 9	− 8	− 8	− 7	− 3	+ 5	+16	+26	+28	+24	+15	+ 9	+ 3	0	− 3	− 6	− 8	− 8	− 9	− 9	− 9	− 9	−10
Means .	−13	−13	−12	−11	−11	−11	− 9	− 3	+10	+27	+38	+42	+34	+22	+ 8	− 2	− 7	−10	−11	−13	−14	−14	−14	−14	−14
Summer.																									
April . . .	−18	−17	−17	−16	−15	−16	−16	−10	+15	+ 42	+59	+61	+46	+35	+ 5	−10	−15	−14	−14	−16	−17	−17	−17	−16	−16
May . . .	−13	−12	−11	−11	−12	−12	− 9	− 5	+11	+32	+46	+48	+41	+26	+ 6	−10	−17	−16	−13	−14	−14	−16	−15	−13	−13
June . . .	− 7	− 8	− 7	− 6	− 6	− 6	− 4	+ 3	+13	+26	+32	+34	+29	+19	+ 4	− 8	−15	−15	−13	−12	−12	−12	−10	− 9	− 7
July . . .	− 9	− 8	− 8	− 7	− 8	− 8	− 6	− 2	+ 6	+19	+29	+36	+35	+25	+12	− 2	−13	−16	−13	−12	−12	−12	−12	−10	− 9
August . . .	−11	−10	−10	− 9	−10	−10	− 8	− 4	+ 9	+26	+34	+38	+33	+22	+11	0	− 8	−11	−10	−12	−13	−13	−13	−11	−11
September .	−14	−14	−13	−12	−12	−12	−13	− 8	+11	+35	+51	+57	+45	+24	+ 3	−11	−17	−16	−12	−15	−17	−16	−16	−15	−14
Means .	−12	−12	−11	−10	−11	−11	− 9	− 4	+11	+30	+42	+46	+38	+23	+ 7	− 7	−14	−15	−13	−14	−14	−14	−14	−12	−12

NOTE.—When the sign is + the H. F. is greater, and when — it is less than the mean.

Hourly Means of Vertical Force in C. G. S. Units (Corrected for temperature) at Kodaikānal from all available days in 1913.

Hours.	Mid.	1	2	3	4	5	6	7	8	9	10	11	Noon.	13	14	15	16	17	18	19	20	21	22	23	Mid.	Means.
Winter. ·02000 C. G. S.+																										
Months.	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ
January	654	654	655	654	654	654	654	655	656	653	646	639	636	635	639	645	649	650	652	652	653	653	653	654	655	650
February	655	657	656	655	655	655	654	655	655	655	654	651	649	648	644	645	646	648	652	654	655	655	655	656	657	653
March	667	667	667	667	666	666	668	668	666	663	657	652	647	648	652	657	661	662	663	663	664	666	667	667	669	662
October	715	715	715	715	715	715	717	717	712	705	697	693	695	698	701	707	710	710	711	711	713	713	714	714	715	710
November	714	714	714	714	714	714	713	713	712	710	708	708	707	705	703	705	706	708	709	710	711	712	712	713	714	710
December	716	716	716	716	716	716	715	713	713	711	710	712	714	715	714	713	713	713	714	714	715	716	717	717	717	714
Means	687	687	687	687	687	687	687	687	686	683	679	676	675	675	676	679	681	682	684	684	685	686	686	687	688	683
Summer.																										
April	678	678	677	677	678	677	681	679	673	665	659	655	652	657	663	670	675	675	674	673	675	677	677	678	678	672
May	683	683	683	682	682	684	687	684	679	671	664	661	661	666	671	678	682	682	680	680	681	681	682	683	683	673
June	691	690	690	690	691	691	693	692	687	682	680	681	681	683	686	690	693	691	688	688	689	689	690	690	691	688
July	694	694	694	694	694	695	697	697	693	689	687	686	685	687	690	694	697	695	692	691	692	693	693	694	695	692
August	703	702	703	703	703	704	706	703	695	688	683	682	685	690	694	698	701	700	698	698	700	701	701	702	703	698
September	708	708	708	708	708	708	711	707	698	689	682	677	680	688	695	702	705	704	702	703	704	705	706	707	708	701
Means	693	693	693	692	693	693	696	694	688	681	676	674	674	679	683	689	692	691	689	689	690	691	692	692	693	688

Diurnal Inequality of the Vertical Force at Kodaikānal as deduced from the preceding Table.

Hours.	Mid.	1	2	3	4	5	6	7	8	9	10	11	Noon.	13	14	15	16	17	18	19	20	21	22	23	Mid.
Winter.																									
1913. Months.																									
January . .	+4	+4	+5	+4	+4	+4	+4	+5	+6	+3	−4	−11	−14	−15	−11	−5	−1	0	+2	+2	+3	+3	+3	+4	+5
February . .	+3	+4	+3	+2	+2	+2	+1	+2	+2	+2	+1	−2	−4	−5	−9	−8	−7	−5	−1	+1	+2	+2	+2	+3	+4
March . . .	+5	+5	+5	+5	+4	+4	+6	+6	+4	+1	−5	−10	−15	−14	−10	−5	−1	0	+1	+1	+2	+4	+5	+5	+7
October . .	+5	+5	+5	+5	+5	+5	+7	+7	+2	−5	−13	−17	−15	−12	−9	−3	0	0	+1	+1	+3	+3	+4	+4	+5
November . .	+4	+4	+4	+4	+4	+4	+3	+3	+2	0	−2	−2	−3	−5	−7	−5	−4	−2	−1	0	+1	+2	+2	+3	+4
December . .	+2	+2	+2	+2	+2	+2	+1	−1	−1	−3	−4	−2	0	+1	0	−1	−1	−1	0	0	+1	+2	+3	+3	+3
Means .	+4	+4	+4	+4	+4	+4	+4	+4	+3	0	−4	−7	−8	−8	−7	−4	−2	−1	+1	+1	+2	+3	+3	+4	+5
Summer.																									
April . . .	+6	+6	+5	+5	+6	+5	+9	+7	+1	−7	−13	−17	−20	−15	−9	−2	+3	+3	+2	+1	+3	+5	+5	+6	+6
May . . .	+5	+5	+5	+4	+4	+6	+9	+6	+1	−7	−14	−17	−17	−12	−7	0	+4	+4	+2	+2	+3	+3	+4	+5	+5
June . . .	+3	+2	+2	+2	+3	+3	+5	+4	−1	−6	−8	−7	−7	−5	−2	+2	+5	+3	0	0	+1	+1	+2	+2	+3
July . . .	+2	+2	+2	+2	+2	+3	+5	+5	+1	−3	−5	−6	−7	−5	−2	+2	+5	+3	0	−1	0	+1	+1	+2	+3
August .	+5	+4	+5	+5	+5	+6	+8	+5	−3	−10	−15	−16	−13	−8	−4	0	+3	+2	0	0	+2	+3	+3	+4	+5
September . .	+7	+7	+7	+7	+7	+7	+10	+6	−3	−12	−19	−24	−21	−13	−6	+1	+4	+3	+1	+2	+3	+4	+5	+6	+7
Means .	+5	+5	+5	+4	+5	+5	+8	+6	0	−7	−12	−14	−14	−9	−5	+1	+4	+3	+1	+1	+2	+3	+4	+4	+5

NOTE.—When the sign is + the Vertical Force is greater, and when —, it is less than the mean.

Hourly Means of the Dip as determined at Kodaikānal from all available days in 1913.

Hours.	Mid.	1	2	3	4	5	6	7	8	9	10	11	Noon.	13	14	15	16	17	18	19	20	21	22	23	Mid.	Means.
N. 4°+													Winter.													
Months.	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′
January .	2·6	2·6	2·7	2·6	2·6	2·6	2·6	2·7	2·7	2·3	1·6	0·9	0·6	0·6	1·1	1·8	2·2	2·3	2·4	2·5	2·6	2·6	2·6	2·6	2·7	2·2
February .	2·9	2·9	2·8	2·8	2·8	2·7	2·6	2·7	2·6	2·5	2·4	2·1	1·9	1·9	1·6	1·7	1·9	2·1	2·5	2·7	2·8	2·8	2·8	2·9	2·9	2·5
March .	3·9	3·9	3·9	3·9	3·8	3·8	4·0	3·9	3·7	3·2	2·6	2·0	1·6	1·8	2·3	2·9	3·3	3·4	3·5	3·5	3·6	3·8	3·9	3·9	4·1	3·3
October .	8·2	8·2	8·2	8·2	8·2	8·2	8·4	8·3	8·3	7·0	6·1	5·8	6·0	6·4	6·8	7·4	7·7	7·7	7·8	7·8	8·0	8·0	8·1	8·1	8·2	7·6
November .	8·1	8·1	8·1	8·1	8·1	8·1	7·9	7·9	7·7	7·4	7·2	7·2	7·2	7·1	6·9	7·2	7·3	7·5	7·6	7·7	7·8	7·9	7·9	8·0	8·1	7·7
December .	8·2	8·2	8·2	8·2	8·2	8·2	8·1	7·9	7·8	7·6	7·4	7·7	7·9	8·0	8·0	7·9	7·9	7·9	8·0	8·0	8·1	8·2	8·3	8·3	8·8	8·0
Means .	5·7	5·7	5·7	5·6	5·6	5·6	5·6	5·6	5·5	5·0	4·6	4·3	4·2	4·3	4·5	4·8	5·1	5·2	5·3	5·4	5·5	5·6	5·6	5·6	5·7	5·2
													Summer.													
April . .	4·9	4·9	4·8	4·8	4·9	4·8	5·2	4·9	4·2	3·3	2·7	2·3	2·1	2·7	3·4	4·1	4·6	4·6	4·5	4·4	4·6	4·8	4·8	4·9	4·9	4·2
May . .	5·3	5·3	5·3	5·2	5·2	5·4	5·7	5·4	4·8	3·9	3·2	2·9	3·0	3·5	4·1	4·8	5·3	5·2	5·0	5·0	5·1	5·2	5·2	5·3	5·3	4·8
June . .	6·0	5·9	5·9	5·9	6·0	6·0	6·1	6·0	5·5	4·9	4·7	4·8	4·8	5·1	5·4	5·9	6·2	6·0	5·7	5·7	5·8	5·8	5·9	5·9	6·0	5·7
July . .	6·3	6·3	6·3	6·3	6·3	6·4	6·5	6·5	6·1	5·6	5·4	5·2	5·2	5·4	5·8	6·2	6·6	6·4	6·1	6·0	6·1	6·2	6·2	6·3	6·4	6·1
August .	7·1	7·0	7·1	7·1	7·1	7·1	7·3	7·0	6·2	5·5	4·9	4·8	5·1	5·7	6·1	6·5	6·9	6·8	6·6	6·6	6·8	6·9	6·9	7·0	7·1	6·5
September .	7·5	7·5	7·5	7·5	7·5	7·5	7·8	7·4	6·5	5·5	4·8	4·3	4·6	5·5	6·2	7·0	7·3	7·2	7·0	7·1	7·2	7·3	7·4	7·5	7·5	6·8
Means .	6·2	6·2	6·2	6·1	6·2	6·2	6·4	6·2	5·6	4·8	4·3	4·1	4·1	4·7	5·2	5·8	6·2	6·0	5·8	5·8	5·9	6·0	6·1	6·2	6·2	5·7

Diurnal Inequality of the Dip at Kodaikānal as deduced from the preceding Table.

Hours.	Mid.	1	2	3	4	5	6	7	8	9	10	11	Noon.	13	14	15	16	17	18	19	20	21	22	23	Mid.
Winter.																									
1913 Months.	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′
January	+0·4	+0·4	+0·5	+0·4	+0·4	+0·4	+0·4	+0·5	+0·5	+0·1	−0·6	−1·3	−1·6	−1·6	−1·1	−0·4	0·0	+0·1	+0·2	+0·3	+0·4	+0·4	+0·4	+0·4	+0·5
February	+0·4	+0·4	+0·3	+0·3	+0·3	+0·2	+0·1	+0·2	+0·1	0·0	−0·1	−0·4	−0·6	−0·6	−0·9	−0·8	−0·6	−0·4	0·0	+0·2	+0·3	+0·3	+0·3	+0·4	+0·4
March	+0·6	+0·6	+0·6	+0·6	+0·5	+0·5	+0·7	+0·6	+0·4	−0·1	−0·7	−1·3	−1·7	−1·5	−1·0	−0·4	0·0	+0·1	+0·2	+0·2	+0·3	+0·5	+0·6	+0·6	+0·8
October	+0·6	+0·6	+0·6	+0·6	+0·6	+0·6	+0·8	+0·7	+0·7	−0·6	−1·5	−1·8	−1·6	−1·2	−0·8	−0·2	+0·1	+0·1	+0·2	+0·2	+0·4	+0·4	+0·5	+0·5	+0·6
November	+0·4	+0·4	+0·4	+0·4	+0·4	+0·4	+0·2	+0·2	0·0	−0·3	−0·5	−0·5	−0·5	−0·6	−0·8	−0·5	−0·4	−0·2	−0·1	0·0	+0·1	+0·2	+0·2	+0·3	+0·4
December	+0·2	+0·2	+0·2	+0·2	+0·2	+0·2	+0·1	−0·1	−0·2	−0·4	−0·6	−0·3	−0·1	0·0	0·0	−0·1	−0·1	−0·1	0·0	0·0	+0·1	+0·2	+0·3	+0·3	+0·3
Means	+0·5	+0·5	+0·5	+0·4	+0·4	+0·4	+0·4	+0·4	+0·3	−0·2	−0·6	−0·9	−1·0	−0·9	−0·7	−0·4	−0·1	0·0	+0·1	+0·2	+0·3	+0·4	+0·4	+0·4	+0·5
Summer.																									
April	+0·7	+0·7	+0·6	+0·6	+0·7	+0·6	+1·0	+0·7	0·0	−0·9	−1·5	−1·9	−2·1	−1·5	−0·8	−0·1	+0·4	+0·4	+0·3	+0·2	+0·4	+0·6	+0·6	+0·7	+0·7
May	+0·5	+0·5	+0·5	+0·4	+0·4	+0·6	+0·9	+0·6	0·0	−0·9	−1·6	−1·9	−1·8	−1·3	−0·7	0·0	+0·5	+0·4	+0·2	+0·2	+0·3	+0·4	+0·4	+0·5	+0·5
June	+0·3	+0·2	+0·2	+0·2	+0·3	+0·3	+0·4	+0·3	−0·2	−0·8	−1·0	−0·9	−0·9	−0·6	−0·3	+0·2	+0·5	+0·3	0·0	0·0	+0·1	+0·1	+0·2	+0·2	+0·3
July	+0·2	+0·2	+0·2	+0·2	+0·2	+0·3	+0·4	+0·4	0·0	−0·5	−0·7	−0·9	−0·9	−0·7	−0·3	+0·1	+0·5	+0·3	0·0	−0·1	0·0	+0·1	+0·1	+0·2	+0·3
August	+0·6	+0·5	+0·6	+0·6	+0·6	+0·6	+0·8	+0·5	−0·3	−1·0	−1·6	−1·7	−1·4	−0·8	−0·4	0·0	+0·4	+0·3	+0·1	+0·1	+0·3	+0·4	+0·4	+0·5	+0·6
September	+0·7	+0·7	+0·7	+0·7	+0·7	+0·7	+1·0	+0·6	−0·3	−1·3	−2·0	−2·5	−2·2	−1·3	−0·6	+0·2	+0·5	+0·4	+0·2	+0·3	+0·4	+0·5	+0·6	+0·7	+0·7
Means	+0·5	+0·5	+0·5	+0·4	+0·5	+0·5	+0·7	+0·5	−0·1	−0·9	−1·4	−1·6	−1·6	−1·0	−0·5	+0·1	+0·5	+0·3	+0·1	+0·1	+0·2	+0·3	+0·4	+0·5	+0·5

NOTE.—When the sign is + the Dip is more, and when — it is less than the mean.

BASE LINES.

No. 19 PARTY.

BY MR. J. DE GRAAFF HUNTER, M.A.

I.—Standard Bars.

PERSONNEL.

Imperial Officers.

Major E. A. Tandy, R.E., in charge up to 16th March 1914.

Lieutenant A. A. Chase, R.E., in charge from 17th March to 8th September 1914.

Major H. L. Crosthwait, R.E., in charge from 9th September 1914.

Lower Subordinate Service.

3 Computers, etc.

The new base line equipment comprises the following standard bars :—

1. 4-metre nickel-steel (42%) bar.*
2. 4-metre invar bar.*
3. 1-metre nickel bar.*
4. 1-metre invar bar.
5. 1-metre nickel-steel (42%) bar.
6. 1-metre silica bar.†

The first five bars and certificates of their lengths have been received. The silica bar has not yet been received and its probable time of arrival is still unknown. Some data from the certificates are given below. Temperatures are always on the hydrogen scale.

4-metre nickel-steel (42%) bar.—This bar was tested at the National Physical Laboratory, Teddington. It has two independent graduations, one on the "baros" plugs and one on the solid metal beside the plugs. In addition there are graduations at each metre on one edge of the upper surface of the bar, and on each edge of the corresponding side.

Graduations.	Actual lengths at 20° C.
On the "baros" plugs	4·000,613 metres
On the solid metal—	
0—1 metre	1·000,164 "
0—2 "	2·000,314 "
0—3 "	3·000,470 "
0—4 "	4·000,617 "

The length at temperature "t°" is given in terms of that at temperature zero by the following formula :—

$$L_t = L_0\,(1 + 0{\cdot}000{,}007{,}52_9 t - 0{\cdot}000{,}000{,}000{,}_3 t^2)$$

and the mean coefficient of expansion between 0° and 30°C may be taken as 0·000,007,519 per degree C, to a high degree of accuracy.

4-metre invar bar.—The bar was tested at the National Physical Laboratory, and has two independent graduations, one on the "baros" plugs, and one on the solid metal beside the plugs. There are also graduations at each decimetre, the first decimetre being divided into millimetres. There are further two other graduations, one on each edge, the sides being cut away to the neutral plane for this purpose. In addition there are graduations at each metre, with the exception of the ends, on one of the top edges of the bar.

Graduations.	Actual lengths at 20° C.
On the "baros" plugs	4·000,160 metres
On the solid metal beside the plugs—	
0—1 metre	1·000,042 "
0—2 "	2·000,078 "
0—3 "	3·000,115 "
0—4 "	4·000,162 "
At the edge, on the same side of the neutral axis as the mark "S. I. P. Geneve"	4·000,157 "
At the edge, on the same side of the neutral axis as the mark "Invar Coulee 2977"	4·000,160 "

* *Vide* Report of the National Physical Laboratory for the year 1913-14, p. 71 *et seq.*

† *Vide* p. 92 *idem.*

The length at temperature "t°" is given in terms of that at temperature zero by the following formula:—

$$L_t = L_0\ (1 + 0{\cdot}000{,}001{,}45_0 t - 0{\cdot}000{,}000{,}000{,}_5 t^2)$$

and the mean coefficient of expansion between 0° and 30° C may be taken as 0·000,001,436 per 1° C to a high degree of accuracy.

1-metre nickel bar.—This bar was tested at the National Physical Laboratory in February 1914. It is graduated on the neutral plane into centimetres throughout, the first and last being further divided into millimetres. Adjoining the zero and 100-centimetre graduations both inside and outside the metre length, are millimetres divided into tenths.

Graduations.		Actual lengths at 20° C.
0—1	mm.	$1{\cdot}000_2$ m.m.
0—2	"	$1{\cdot}999_6$ "
0—3	"	$3{\cdot}000_5$ "
0—4	"	$4{\cdot}001_0$ "
0—5	"	$5{\cdot}001_6$ "
0—6	"	$6{\cdot}001_5$ "
0—7	"	$7{\cdot}001_8$ "
0—8	"	$8{\cdot}001_9$ "
0—9	"	$9{\cdot}002_3$ "
0—10	"	$10{\cdot}002_4$ "
0—990	"	$990{\cdot}266_5$ "
0—991	"	$991{\cdot}267_0$ "
0—992	"	$992{\cdot}266_9$ "
0—993	"	$993{\cdot}267_2$ "
0—994	"	$994{\cdot}267_3$ "
0—995	"	$995{\cdot}267_7$ "
0—996	"	$997{\cdot}267_4$ "
0—997	"	$997{\cdot}268_1$ "
0—998	"	$998{\cdot}268_0$ "
0—999	"	$999{\cdot}268_0$ "
0—1000	"	$1000{\cdot}270_4$ "

The length of the bar at temperature "t°" is given in terms of that at temperature zero by the following formula:—

$$L_t = L_0\ (1 + 0{\cdot}000{,}012{,}428t + 0{\cdot}000{,}000{,}00759t^2).$$

The scale was also tested at the Bureau International des Poids et Mesures, Sèvres, in September 1913 and the length 0—1000mm. was found to be—

$$\overset{m}{1}{\cdot}000{,}018{,}4\ (1 + 0{\cdot}000{,}012{,}478t + 0{\cdot}000{,}000{,}005{,}63t^2).$$

The length at 20° C deduced from this is $\overset{m}{1}{\cdot}000{,}2702$.

1-metre invar bar.—This bar was examined at the Bureau International des Poids et Mesures. It is divided into centimetres from 0 to 100, the terminal centimetres being divided into millimetres. The graduations are continued one millimetre at each end, and these two millimetres are sub-divided into tenths.

Its length at temperature t° C was found to be—

$$\overset{m}{1}{\cdot}000{,}008{,}6(1 + 0{\cdot}000{,}001{,}510t - 0{\cdot}000{,}000{,}000{,}69t^2).$$

1-metre nickel-steel (42 %) bar.—This bar was sent to the Bureau International des Poids et Mesures before it was completed, and only the expansion was examined. The length at temperature "t°" in terms of that at temperature zero is given by the following formula:—

$$L_t = L_0\ (1 + 0{\cdot}000{,}007{,}704t - 0{\cdot}000{,}000{,}003{,}25t^2)$$

1-metre silica bar.—This bar has been under test at the National Physical Laboratory. The secular change of length of silica has only been under consideration in recent years, and some further time must elapse before this bar is

available. A reference to the bar may be found in the National Physical Laboratory Report 1913-14.

The following note is extracted from a letter dated 21st May, 1914, from the Director, National Physical Laboratory, Teddington, to the Director-General of Stores:

"With regard to the silica metre we have considered it desirable, as the "result of our last measurements to keep this under observation a little longer, "before undertaking the final platinizing and annealing. We had supposed that "the bar was practically constant in length, but this result appears to have been "due to an accidental distribution of experimental errors in the earlier observa- "tions, and it now seems probable that the bar is growing at the rate of 2 μ per "annum. We think it best, therefore, to extend observations for a few months "more in order to confirm this definitely, before removing the temporary gradu- "ations with which we are now working. It is not certain how long we may "find it necessary to keep the bar under observation after the final graduations "are put on, but the end of this year would be the very earliest date at which "it might be safe for us to hand the bar over to you as a permanent standard."

The proposal for the present retention of the silica bar at Teddington for further examination was duly assented to.

II.—Thermometers.

There are two Baudin thermometers which have been examined at the Bureau International des Poids et Mesures. These are for the highest precision temperature measurements and the corrections are given to 0°·001 C.

The corrections are six in number :—

1. For calibration.
2. For interior pressure.
3. For exterior pressure.
4. For the zero point.
5. For the fundamental interval.
6. Correction to the hydrogen scale.

In reading, the thermometer must be exposed at least as far as the extremity of the column, to the temperature to be measured, and a determination of the zero must be made immediately afterwards. For further particulars reference must be made to the certificate and accompanying papers in the Stores section of the Trigonometrical Survey Office.

There are also 18 thermometers by Messrs. S. and A. Calderara, London, with National Physical Laboratory certificates. The corrections of these are given to the nearest 0°·01 C, and give temperatures on the hydrogen scale. The corrections are applicable to the readings of the thermometers when in a horizontal position. If they are used in a vertical position an additional correction is necessary. This is shown in the last column of the following table, each number applying to all the thermometers for the range of temperature between the heavy lines.

Correction to thermometers in horizontal position.

THERMOMETER NUMBER.	18570	18571	18572	18573	18574	18575	18576	18577	18578	18579	18580	18581	18582	18583	18584	18585	18586	18587	Further correction when thermometer is vertical.
Temperature.	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	
0° C	+0·05	+0·05	+0·07	+0·05	+0·04	+0·02	+0·02	−0·01	+0·02	+0·06	+0·01	0·00	+0·05	+0·05	+0·01	+0·06	+0·03	+0·02	+0·01
2	+0·02	+0·01	+0·05	+0·02	+0·02	0·00	+0·01	−0·03	+0·01	+0·05	0·00	−0·02	+0·04	+0·04	+0·01	+0·04	0·00	0·00	
4	+0·01	0·00	+0·04	+0·02	+0·02	0·00	+0·01	−0·02	+0·01	+0·03	+0·01	−0·02	+0·05	+0·05	0·00	+0·04	+0·01	+0·01	
6	+0·01	0·00	+0·05	+0·01	+0·02	0·00	+0·01	−0·01	+0·01	+0·01	0·00	−0·03	+0·04	+0·06	−0·01	+0·02	−0·01	−0·01	
8	+0·01	+0·01	+0·03	+0·01	+0·01	0·00	0·00	0·00	+0·02	+0·02	+0·01	−0·02	+0·04	+0·08	+0·01	+0·04	0·00	+0·01	
10	+0·02	+0·01	+0·02	+0·01	+0·03	+0·02	−0·01	+0·03	+0·03	+0·01	−0·01	−0·02	+0·02	+0·04	+0·02	+0·02	0·00	0·00	+0·02
12	0·00	+0·01	+0·01	−0·02	+0·03	+0·01	0·00	+0·02	+0·02	+0·03	+0·01	0·00	+0·04	+0·05	+0·03	+0·04	−0·01	+0·02	
14	+0·01	+0·01	+0·01	−0·01	+0·03	+0·01	+0·01	+0·02	+0·02	+0·01	+0·01	0·00	+0·04	+0·04	+0·04	+0·05	−0·01	+0·02	
16	+0·01	+0·01	+0·02	−0·01	+0·05	+0·02	+0·02	+0·03	+0·03	+0·01	+0·01	−0·01	+0·05	+0·05	+0·05	+0·06	−0·02	+0·03	
18	+0·03	+0·01	+0·02	−0·01	+0·05	+0·02	+0·04	+0·04	+0·04	+0·01	+0·01	−0·01	+0·05	+0·05	+0·04	+0·05	−0·02	+0·02	
20	+0·04	+0·02	+0·02	0·00	+0·03	+0·02	+0·03	−0·01	+0·03	+0·03	+0·01	−0·01	+0·04	+0·04	+0·04	+0·04	−0·01	+0·02	+0·03
22	+0·04	+0·04	+0·04	0·00	+0·03	+0·02	+0·03	−0·01	+0·03	+0·03	+0·01	−0·01	+0·03	+0·03	+0·04	+0·04	0·00	+0·02	
24	+0·04	+0·05	+0·05	−0·01	+0·02	+0·03	+0·05	−0·01	+0·02	+0·05	+0·02	−0·01	+0·03	+0·03	+0·05	+0·05	0·00	+0·03	
26	+0·04	+0·05	+0·06	−0·02	+0·02	+0·03	+0·04	−0·02	+0·01	+0·05	+0·02	−0·01	+0·04	+0·03	+0·06	+0·06	+0·01	+0·04	
28	+0·04	+0·05	+0·04	−0·01	+0·03	+0·05	+0·05	−0·01	+0·02	+0·05	+0·02	0·00	+0·03	+0·02	+0·07	+0·06	+0·01	+0·04	
30	+0·04	+0·05	+0·02	+0·01	+0·03	+0·06	+0·05	+0·01	+0·03	+0·05	+0·02	0·00	+0·02	+0·02	+0·04	+0·06	+0·02	+0·03	
32	+0·05	+0·05	+0·02	+0·01	+0·03	+0·05	+0·05	+0·03	+0·03	+0·05	+0·03	0·00	+0·02	+0·01	+0·06	+0·06	+0·02	+0·04	
34	+0·06	+0·07	+0·02	+0·02	+0·03	+0·06	+0·07	+0·03	+0·04	+0·05	+0·04	+0·01	+0·03	+0·01	+0·06	+0·04	+0·02	+0·04	+0·04
36	+0·06	+0·06	+0·03	+0·04	+0·04	+0·06	+0·07	+0·05	+0·06	+0·06	+0·06	+0·02	+0·04	0·00	+0·07	+0·05	+0·01	+0·05	
38	+0·06	+0·05	+0·04	+0·04	+0·03	+0·07	+0·06	+0·05	+0·06	+0·07	+0·06	+0·03	+0·05	0·00	+0·07	+0·04	+0·03	+0·05	
40	+0·05	+0·05	+0·06	+0·04	+0·03	+0·05	+0·05	+0·05	+0·07	+0·06	+0·07	+0·04	+0·07	+0·04	+0·07	+0·04	+0·03	+0·06	
42	+0·03	+0·06	+0·06	+0·05	+0·04	+0·05	+0·05	+0·05	+0·06	+0·05	+0·07	+0·03	+0·07	+0·06	+0·07	+0·04	+0·03	+0·06	
44	+0·03	+0·07	+0·06	+0·05	+0·04	+0·05	+0·04	+0·02	+0·05	+0·06	+0·07	+0·03	+0·07	+0·07	+0·07	+0·04	+0·04	+0·06	
46	+0·04	+0·08	+0·06	+0·05	+0·05	+0·07	+0·04	+0·02	+0·06	+0·08	+0·08	+0·04	+0·07	+0·09	+0·08	+0·07	+0·05	+0·07	
48	+0·05	+0·07	+0·05	+0·05	+0·05	+0·09	+0·05	+0·02	+0·07	+0·00	+0·07	+0·05	+0·06	+0·10	+0·07	+0·07	+0·06	+0·06	+0·05
50° C	+0·06	+0·07	+0·02	+0·04	+0·05	+0·07	+0·06	+0·02	+0·06	+0·09	+0·05	+0·05	+0·04	+0·09	+0·05	+0·07	+0·05	+0·06	

Fig. 1.

DIAGRAM (not to scale) showing the connections of Latitude stations between Dehra Dun and Rajpur by triangulation and by traverse.

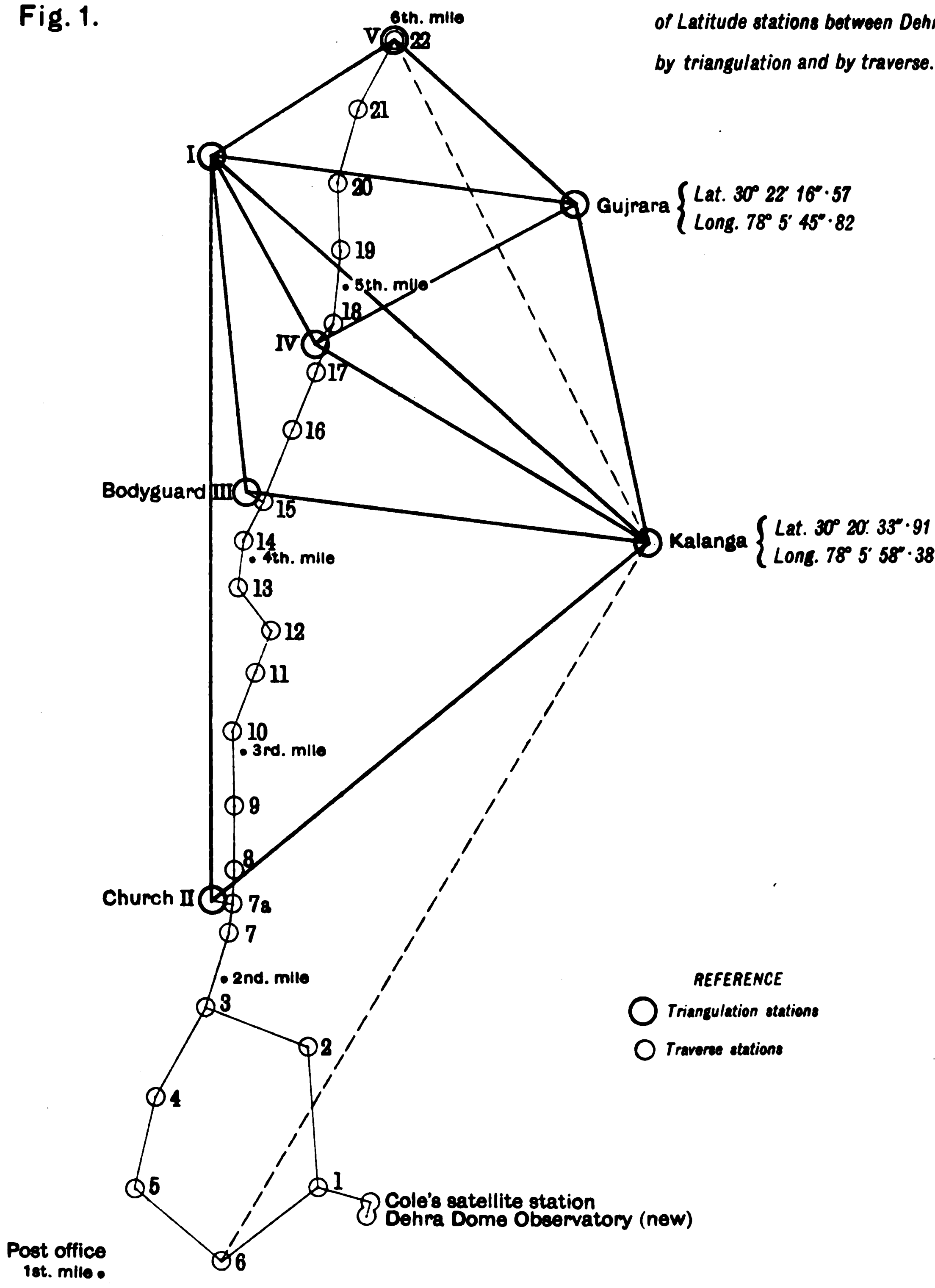
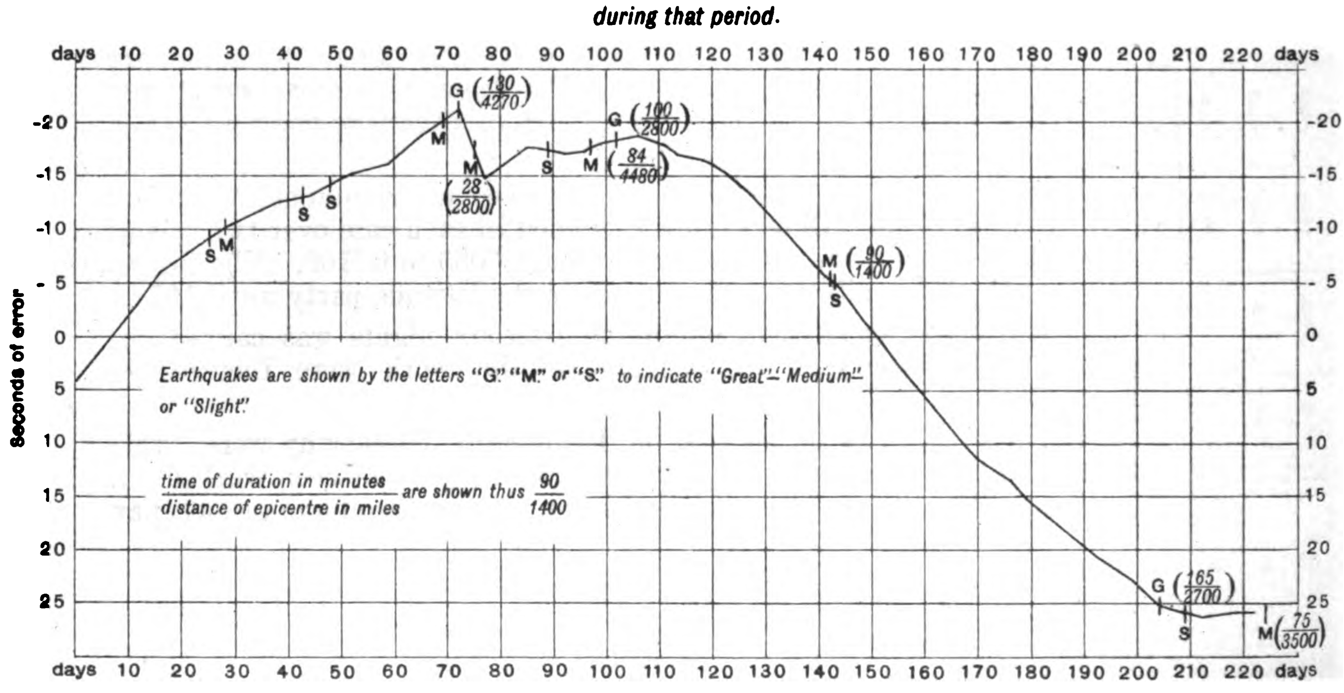


Fig. 2. — *Showing changes of rate in Clock "A," March-October 1914, and also all earth tremors recorded on the seismograph during that period.*



COMPUTING AND TECHNICAL OFFICES.

BY MR. J. DE GRAAFF HUNTER, M.A.

I.—Plumbline deflections near Dehra Dūn and Mussoorie.

PERSONNEL.

Imperial Officers.

Mr. J. de Graaff Hunter, M.A., in charge.
Lt. R. L. Almond, R.E., 1912-13.
„ F. P. Nosworthy, R.E., 1913-14.
„ H. M. McKay, R.E., 1912-13.

Provincial Officer.

Mr. Hanuman Prasad.

Computing Office.

Babu Ishan Chandra Deb, B.A., and eleven computers.

Upper Subordinate Service.

Mr. Sarat Kumar Mukerji.

The Royal Engineer Officers mentioned in the margin were under instruction for some months between December 1912 and March 1914. It was decided to take the opportunity of studying the irregularities of the geoid in the neighbourhood of Dehra Dūn and Mussoorie. The programme decided on for the spring of 1913 comprised:—

(1) A careful crinoline chain traverse from Dehra Dūn, following the road, to Rājpur.

(2) Minor triangulation from the base Kalanga-Gujrara, fixing independently some of the points on the traverse and in addition two points on the hill side, between Rājpur and Mussoorie.

(3) Observations for latitude at four traverse stations between Dehra and Rājpur, and two stations between Rājpur and Mussoorie, and also at Nāg Tiba.

Traverse.—The traverse (*vide* Fig. 1) begins from Cole's Satellite Station, which is 61·26 feet (mean of 1913 and 1914 values) and bears 6° 12′ 16″ east of north from Dehra Dūn Dome Observatory (new), generally known now as the small Photo-helio Observatory. The observatory mark is covered by the photo heliograph, and so is not accessible for observing from.

A 300-foot crinoline chain and a five-inch microscope theodolite were used.

Stations (1) to (6) form a closed circuit; its angular error of closing was zero, and the linear error was 3 feet in 1¾ miles, or about 1 in 3,000. Stations (6) to (22) do not form a closed circuit, but closing of angles was effected by observing Kalanga from both terminal stations, the closing error being 43″ or about 2″ per angle. The linear error between stations (3) and (22) was 1 in 9,000 as ascertained by connecting the traverse with triangulation at four points. There is however a nearly constant error of ten feet between the triangulation based on Kalanga-Gujrara and the traverse based on Dehra Dome Observatory (new); and it appears that this is very likely due to the triangulation between Kalanga and the Dome Observatory. Although these stations are less than four miles apart the triangulation linking them is by no means direct, as may be seen from the diagram. It is intended to make a direct connection when opportunity offers.

Triangulation.—The triangulation was carried out with a five-inch microscope theodolite. The ray Kalanga-Gujrara, previously fixed by secondary and minor triangulation, was used as a base. The mean triangular error was 5″. Observations were taken on three zeros, and on each zero one observation was taken on each face.

Latitudes.—Astronomic latitudes were observed at triangulation stations III, IV, V, VI, VIII, IX. Observations extended in each case over two nights and the probable errors of the results varied from 0·″085 to 0·″169. The instrument used was the old zenith telescope, in use in the latitude party until 1911.

A full programme for latitude, extending over six nights was carried out at Nāg Tiba. The observers for this part of the work were Lieutenants Almond and McKay.

Azimuths.—In 1913-14 the services of Lieutenant Nosworthy were available. By this time the results of the latitude observations had been worked out and it was seen that the variation of deflection of the plumbline in meridian

between Dehra and Rājpur, was very uniform, while between Rājpur and Mussoorie a very large maximum was attained. Azimuth observations were deemed desirable at Rājpur and at the two stations VIII and IX between Rājpur and Mussoorie. Station VIII is close to and on the west of the large landslip on the Rājpur-Mussoorie road, and was named "Spur Point." Station IX is at Jharīpānī. The latitude pillar of the previous season had disappeared owing to building operations, and so another was built as close by as necessary and convenient. The Rājpur latitude station of 1892 could not be identified with certainty, and a pillar was also built close by.

It was necessary first of all to have rays from the three azimuth stations whose geodetic azimuths were known. If the stations had been visible from the Dehra Dome Observatory, it would have been sufficient to observe the angle between them and Mussoorie Dome Observatory (Evelyn Hall), since the azimuth of the Dehra-Mussoorie ray was known. Then the reverse azimuths of the rays could have been computed with only an approximate knowledge of the lengths of the rays. None of the stations were visible from the Dehra Observatory and it became necessary to select a new station. A suitable place was found in the compound of Dālanwāla House, from which a wide view of the hills can be obtained. The station was built and its distance from the Dome Observatory fixed by careful traverse. Only one intermediate station between it and Cole's Satellite Station was found necessary.

Three measurements of both of the traverse rays were made. The results for the first were 983 ft. $\frac{3}{8}$ in., 983 ft. $\frac{1}{8}$ in. and 983 ft. $\frac{1}{8}$ in., and for the second ray 1,211 ft. $5\frac{1}{8}$ in., 1,211 ft. $4\frac{3}{8}$ in., and 1,211 ft. $5\frac{3}{8}$ in., the worst discrepancy being 1 in 14,000. The two angular measurements were made with an 8-inch theodolite. It appears that the position of Dālanwāla Station with reference to the Dome Observatory is known correct to half an inch.

The distance and bearing of Dālanwāla Station being fixed, it was possible to compute the angle subtended at Mussoorie by Dālanwāla and Dehra Dome Stations, and thus the azimuth of Dālanwāla from Mussoorie was found to be 3° 57′ 23″·16, and the reverse azimuth was computed. The angles at Dālanwāla between Mussoorie, Jharīpānī, Spur Point and Rājpur (azimuth) were then observed with 12-inch theodolite No. III, and the following results were found.

Azimuths at Dālanwāla.

Mussoorie (*Dome Observatory*)	183° 57′ 3″·04
Jharīpānī (*Azimuth station*)	194° 24′ 26″·26
Spur Point (*Latitude and azimuth station*)	197° 58′ 49″·83
Rājpur (*azimuth station*)	204° 14′ 10″·40

The next step was to compute the reverse azimuths of Dālanwāla from Jharīpānī, Spur Point and Rājpur; after which full azimuth programmes were observed with the 12-inch theodolite at each station. The position of Rājpur station was approximately fixed by observing the angle between Spur Point and Dālanwāla.

Descriptions of Stations.

Dālanwāla Station.—Consists of an isolated pillar 3 ft. 4 in. in diameter, flush with the ground and surrounded by a masonry platform. It is situated in the north-east corner of Dālanwāla compound on the right bank of the Rispana nala. One quarter of a bigha of land, purchased for the purpose, is enclosed by a fence.

Rājpur Azimuth Station.—Consists of a brick-in-lime pillar 1 ft. 4 in. square surrounded by a brick-in-lime platform about 10 ft. square. It is situated at the south-east extremity of the field behind Ravenswood Cottage, and is approximately 123 ft. from the old Rājpur latitude station, the bearing of which is 33° east of north.

Spur Point Latitude and Azimuth Station.—Was built in 1913 and consists of the ordinary form of latitude pillar, but is not isolated. It is situated on a steep spur on the west side of a big landslip. It can be reached by leaving

the pony road between Rājpur and Mussoorie at a point about 1½ miles above the toll bar.

Jharīpānī Azimuth Station.—Is situated on the extreme south-west corner of the plateau on which Oak Grove Boy's School is built, and is on the edge of the compound of a bungalow built in 1913 by the East Indian Railway for their S. D. O. There are no signs of the latitude pillar of 1913, which is locally reported to have been about 15 feet due east of the new station.

Results.—The following results have been obtained. Values found previously are enclosed in brackets, and are given here for convenience of reference :—

Geodetic Co-ordinates and Plumbline Deflections.

Station.		Latitude.	Longitude.	Deflection.			
				Meridian to N.	Prime Vert. to E.	Resultant.	
						Amount.	Direction, E of N
		° ′ ″	° ′ ″	″	″	″	°
Dehra.	Haig Observatory .	(30 14 28·73)	(78 3 22·12)	(37·5)	(22·7)	(43·8)	(31·2)
	Dome „ .	(30 19 29·13)	(78 3 14·94)	...	...	...	.
	Cole's Satellite .	30 19 29·73	78 3 15·02	...	...	...	...
	Dālanwāla . .	30 19 21·78	78 3 37·64	...	...	...	..
III		30 21 46·61	78 4 7·39	41·0	...	...	...
IV		30 22 8·93	78 4 30·87	42·2	...	...	...
V		30 22 51·83	78 5 21·38	44·4	...	...	...
VI		30 23 30·79	78 6 2·00	45·9	...	...	...
Rājpur . . .		30 23 56·83	78 6 0	(47·7)	32·3	57·6	34·1
VIII. Spur Point .		30 24 37·72	78 5 35·94	53·2	31·3	61·7	30·5
IX. Jharīpānī .		30 25 10·05	78 5 21·53	52·5	33·6	62·3	32·6
Mussoorie Dome Observatory.		(30 27 40·38)	(78 4 17·66)	(36·5)	28·2*	46·1	37·7
Nāg Tiba . .		(30 35 11·57)	(78 9 9·90)	30·5	(23·5)	38·5	37·6

* Observed by the late Lieutenant H. G. Bell, R.E., 1911.

Mean direction of resultant is 34°·0 east of north.

Discussion.—The height of Mussoorie above Dehra Dūn deduced by the ordinary formulæ from numerous observed vertical angles is in excess of that found by spirit levelling by somewhat more than 3 feet (see Prof. Paper No. 11, p. 7). When proper attention is paid to the deflection of the plumbline, and refraction is computed taking account of the decrease with height of the temperature of the atmosphere, the value obtained from the vertical angles agrees more closely with the height found by spirit levelling, corrected for the rise of the geoid relative to the spheroid; and the discrepancy is reduced to 1·94 feet (see Prof. Paper No. 14, p. 22). The rise of the geoid could not be computed with sufficient accuracy until the deflections referred to above had been obtained ; and the discrepancy gave reason to expect that the rise of the geoid had been underestimated ; or, in other words, that the deflections were larger than had been supposed. The recent latitude observations show that the values of the deflections between Dehra and Rājpur could have been obtained with considerable precision by simple interpolation ; but between Rājpur and Mussoorie the deflections are much in excess of what would be found by interpolation, and, incidentally, are the largest deflections ever observed. The net result is to show that the average deflections between Rājpur and Mussoorie are greater by 4″ in meridian and 1″ in prime vertical than would be found by interpolation. These deflections reduce the discrepancy in height alluded to above from 1·94 feet to 1·61 feet. This residual is presumably of the

nature of an error and is to be accounted for by the uncertainties of refraction and instrumental error of graduation; and by errors in the lengths of the levelling staves, and change therein with temperature and humidity. To account entirely for the discrepancy of 1·6 feet an error of 6″·6 in the vertical angle, or one of 1 in 2920 (*i.e.*, 1 mm. in 10 feet) in the levelling staves, must be postulated.

The direction of the resultant deflections does not vary very much, and its mean value is 34°·0 east of north. As regards the meridian deflection at Nāg Tiba, it is worthy of note that the observed value differs only by 0″·8 from a value computed from the actual vertical angles observed there and at Mussoorie to the snow peaks, after making allowance, as fully as is possible at present, for refraction (see Prof. Paper No. 14, p. 41). The interest in the Nāg Tiba deflection lies in the fact that it is the nearest station to the snow peaks, the variation of whose heights it is desired to find.

II.—The Standard Clocks and Chronograph.

For many years the old type of break-circuit for the chronograph, which comprised a toothed wheel on the same spindle as the scape wheel, had given trouble. The same had occurred in the work on the longitude arcs with clocks of similar pattern, and a thorough remedy had never been found. In the spring of 1911 Lieutenant-Colonel G. P. Lenox Conyngham fitted a new form of break-circuit to clock "A" (No. 1135 by Frodsham), consisting of a little wheel attached to the pendulum about two-thirds of the way down. In passing the mid position this presses down a little projection on a spring which also carries a platinum point; and by this means the circuit is broken. The current does not pass through the clock. The interval between successive breaks is not exactly the half period of the pendulum, though it may be adjusted to be very nearly so; but between alternate breaks the interval is precisely that of the pendulum's period. All measurements on the chronograph sheet are accordingly taken from the even seconds.

The new form of break-circuit appeared to have some advantages, but with it when the chronograph was used the rate of the clock was much affected. The reason for this is not clear, seeing that the clock does not form part of the electric circuit. The difficulty, however, was overcome by using a very small current which is always passing through the clock's circuit, and actuating the chronograph through a relay. The necessary relay, resistance and capacity were obtained from Siemens & Co., Calcutta. After this had been done, the clock behaved fairly well — sufficiently so for the magnetic work.

In the autumn of 1913 special attention was directed to the determination of time in view of the wireless longitude operations which were then proposed in collaboration with the de Filippi Expedition. It appeared that the clock "A" was very badly placed—in a position where it was subject to draught and an extreme range of temperature variation. It was decided to brick up part of the passage round the central pillar of the Photo-helio Observatory, leaving access from the transit room. This made a little room well protected from temperature variation. To improve matters still further an enclosure was made within this, and inside this two pillars were built for hanging clocks on. The faces of the two pillars are at right angles to each other, with the object of keeping the oscillations of the two pendulums quite independent. The front of this inner room was glazed, and two clocks "A" and "B" (No. 1134 Frodsham) were hung. The diurnal variation in temperature is scarcely discernible on a thermograph sheet. A third clock "C" ($\overset{\wedge}{_{1133}}$ by Frodsham) has also been hung in the outer room, and is subject to somewhat greater temperature changes. All three clocks are fitted with the same type of break circuit.

Clock "A" has behaved extremely well on its new pillar. Its error, reduced by 3·3 seconds per day, is shown in Fig. 2. The scale is such as to show up any irregularity very markedly; the complete range of variation in the rate is only 0·4 second per day. The greatest irregularities occur between mid-May and mid-July. Mr. E. C. J. Bond made the suggestion that earthquakes might have disturbed the clock, and accordingly the days on which earthquakes

Fig. 3.— CHRONOGRAPH CONNECTIONS

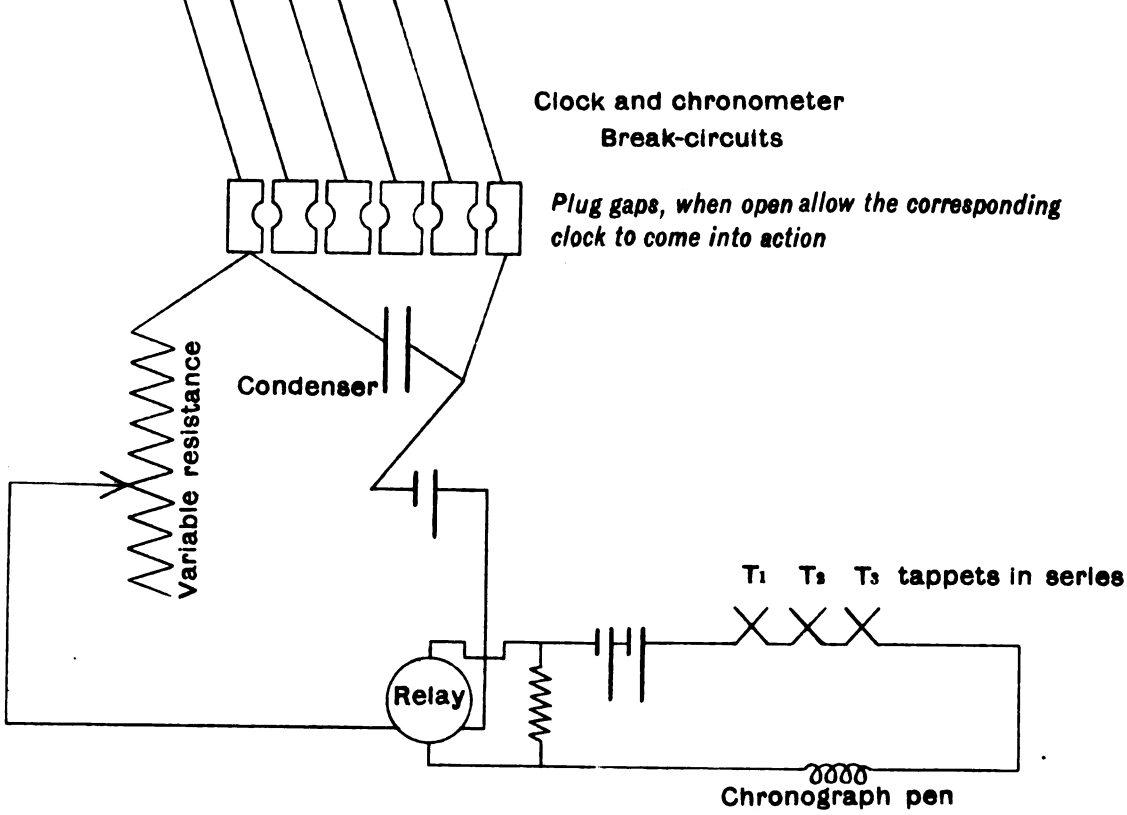


Fig. 4.— WIRELESS CONNECTIONS

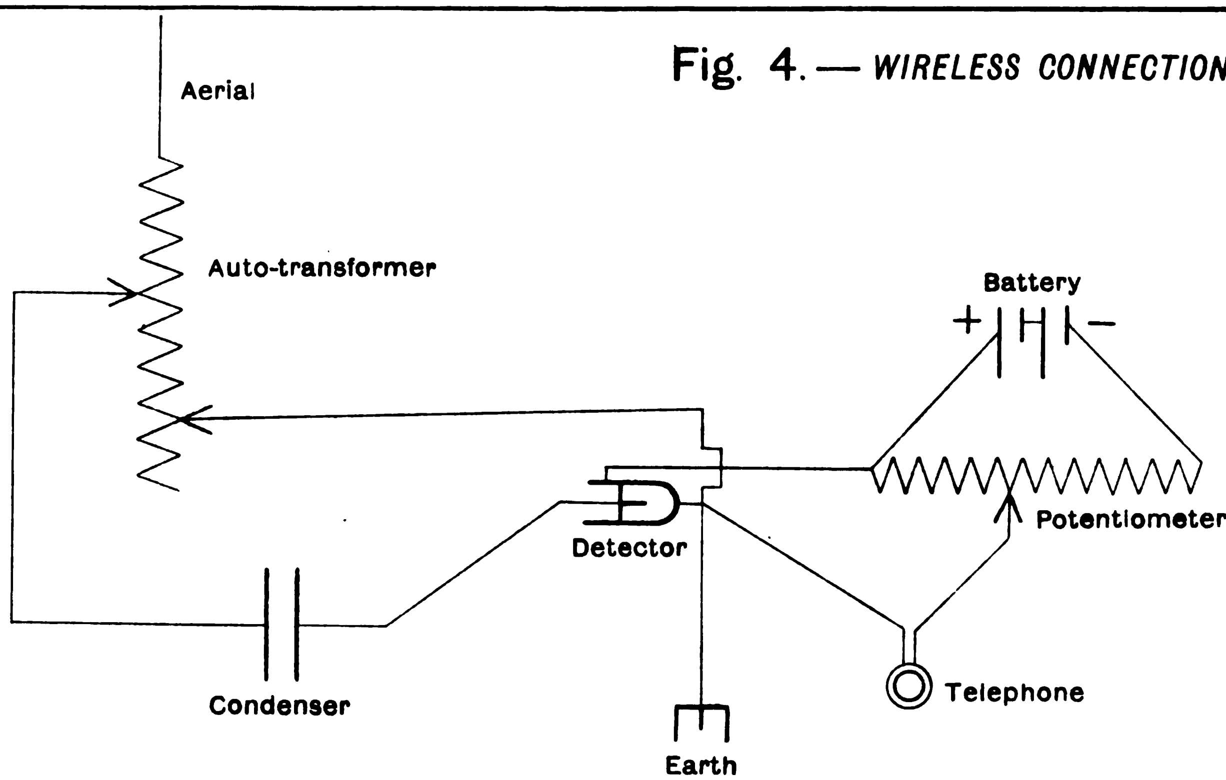
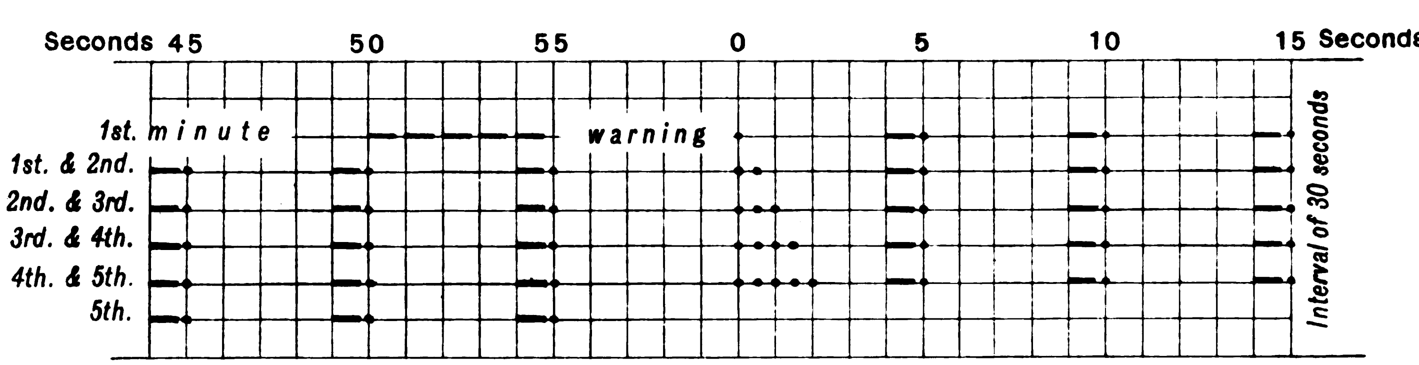


Fig. 5.— A COMPLETE SERIES OF TIME SIGNALS AS SIGNALLED BY THE RADIO OFFICE



NOTE — The actual time signals are the "—•s" in the above list, the moment recorded by the observer being the dot.

have been recorded are marked. It will be seen that where no earthquakes have occurred, the rate has been wonderfully steady.

Clock "B" has not done so well. Clock "C" is intermediate in performance to the other two.

The clock and chronograph connections are shown in Fig. 3; tappets being provided for the transit instrument, the wireless receiver and the magnetic observatory. Any one, any pair, or all three clocks can be run on the chronograph as desired. This gives a convenient way of comparing the clocks, and a comparison is usually made each morning.

Mr. Hanuman Prasad set up one of the longitude transit instruments in 1913, and began observations with the chronograph. Heretofore the time stars had been observed by the eye and ear method. This change marked a considerable advance in the accuracy of time determination.

III.—Wireless Longitudes.

Two members of Cav. de Filippi's Scientific Expedition to the Western Karakoram, Commander Alessio and Professor Abetti, came to Dehra in August 1913. It was then arranged that the Survey of India should collaborate with the Expedition in the determination of longitudes by wireless telegraphy. As the Expedition was going beyond some great Himālayan ranges, it was a little uncertain whether the signals would be successfully received; and to this extent the work was experimental. In addition the work was novel to the officers of the Survey of India. It is satisfactory to be able to state that in all cases attempted the signals have been successfully received both by the Expedition and at Dehra.

During their short stay in Dehra Commander Alessio and Professor Abetti put up their horizontal aerial on the maidan and after some little trouble made their adjustments and received signals from Lahore. After their departure for Kashmīr and Skārdu, correspondence was begun with the Telegraph Department on 13th September, and in due course it was arranged that a wireless operator and the necessary instruments should be lent to the Survey Department for such time as was necessary. Mr. Ross arrived about 10th November, the horizontal antenna on a selected site was set up, and the receiving apparatus was installed at the east end in a tent, near to the southern absolute magnetic house. This aerial, which was 300 metres long stretched across both compounds on insulated supports, its west end being near the western compound wall. It passed about 30 yards north of the Superintendent's office.

On the second day Mr. Ross succeeded in picking up the signals. He remained at Dehra through the first Skārdu set, leaving just before Christmas.

In the meantime, the Expedition had installed their apparatus at Skārdu, and a wire announcing the successful receipt of wireless signals was received on October 30.

Personnel.—There was no officer whose whole time was available for this work, which was accordingly undertaken by volunteers. The preliminary arrangements were made by Mr. Hunter. Major E. A. Tandy, R.E., took charge from November 15th and the observers were then Major Tandy, Mr. Hunter, Mr. Bond and Mr. Hanuman Prasad. In February 1914 Major Tandy handed over to Lieutenant Mason, R.E., after which the observers were Mr. Hunter, Lieutenant Mason, Mr. Bond and Mr. Hanuman Prasad. This arrangement continued until October 17th, when Lieutenant Mason on reversion to military duty handed over charge to Mr. Hunter. By this time work at the last station had commenced, and only one week's observations remained to be completed.

With the Expedition the early observing was all done by Commander Alessio of the Royal Italian Navy and Professor Abetti of Rome Observatory. Later on some observations were taken by Major H. Wood, R.E., Survey Officer with the Expedition, and Marchese Ginori. Various combinations of observers were obtained in all series; but up to date there are no data for determinations of the relative personal equations of the two groups of observers.

Arrangement.—The arrangement adopted for the longitude operations was as follows. Wireless signals were sent from the Radio Office, Lahore, at prearranged times and dates, 90 signals being sent each evening. These signals were recorded on chronographs by the Expedition and at Dehra, in addition to the observation of the times of transit of stars, both before and after the wireless.

The Expedition throughout used a horizontal aerial. At Dehra it was found after some trials that better signals were obtained from a vertical "umbrella" aerial with seven (afterwards reduced to 6) radial wires. For this purpose the mast made in 1912-13 at Dehra (*vide* illustration facing p. 147 of Vol. V of the Records), set up to a height of 98 feet, was used. An immediate advantage of this was that it became possible to remove the receiving apparatus to the transit room. This saved the observer from having to hurry off about a quarter of a mile to the wireless tent, and also gave him a chance of attending to the chronograph if necessary. Attempts to use the horizontal aerial from the transit room failed. The superiority of the vertical aerial was perhaps due to the fact that the survey office compound is heavily wooded.

The wave-length of the signals was originally 1800 metres but was afterwards changed to 2000 metres.

Receiving Apparatus.—The receiving apparatus was as follows (*vide* Fig. 4).

1. Primary circuit, receiving oscillations from the aerial through the auto-transformer to earth.

2. Secondary oscillations induced in auto-transformer coil are carried to earth and one terminal of a condenser. From the other terminal a wire leads to the detector, and a second wire completes the circuit to the other end of the auto-transformer. The property of the detector is to allow current to flow only in one direction. A battery placed across the terminals of a potentiometer makes an adjustable voltage available; and this is applied in series with a telephone receiver across the detector and reinforces the current derived from the wireless, when the potentiometer is suitably adjusted.

It was afterwards found that the auto-transformer could be cut out and that signals were received better without it. This merely meant disconnecting one wire.

A crystal detector has been used throughout, made as follows:—both the Zincite and the telegraph department's "X" crystal were mounted in brass holders by being dropped into dental white which melts at a low temperature. It is important in making up the detector not to make the dental white too hot, as the crystals are apt to fly to dust if this is done.

It was noticed latterly that two or more detectors might be joined in parallel. With this arrangement the signals were received more clearly than with either detector singly. There is also the advantage that when adjustment with one detector is not very satisfactory it is possible, without risk of losing the adjustment altogether, to continue trying for an improved adjustment with the second detector. On nights when atmospherics are troublesome this is advantageous.

The Expedition used both the electrolytic type and the carborundum crystal detector. Their detectors are apparently far more sensitive than ours, as they were unable to receive signals with one of our type of detector, which was sent to them for trial. They speak of their latest type carborundum crystal as "extraordinarily sensitive."

The time signal.—After testing various signals it was found that the most convenient to hear and record was a "dot" preceded by a warning "dash." The actual scheme was as follows. Ten minutes before the actual time signals a series of Bs (dash, dot, dot, dot). were sent for 8 minutes. This was to enable the detector to be adjusted. Then there was an interval of 110 seconds, after which 5 warning dashes were sent. After this a "dot" and then three time signals at 5 seconds interval; thirty seconds interval and then three time signals; five seconds, then two "dots" and three more time signals at 5 seconds intervals. Each group of six time signals were indicated by one, two or more

"dots." A complete set occupied 5½ minutes and three such sets were sent out each evening. The scheme can be clearly seen from the diagram, Fig. 5.

The signals might conveniently be sent at shorter intervals; and an interval differing from an exact number of seconds would prevent the possibility of the signals all coinciding with the "seconds" marks of the chronograph.

Atmospherics.—Atmospheric disturbances greatly hindered the first series with Skārdu in December 1913, but, possibly owing to practice in receiving, the effect of atmospherics was less and less remarked in the subsequent series up to April, every signal during the Leh series (March 25 to April 1) being distinctly heard. It had been supposed that atmospherics would grow worse from March onwards until August, and that the reception of signals might then prove impossible. Happily this was not the case.

A careful record of happenings was made of Depsang Series (Jun. 3-8) on the first two nights of which local thunderstorms completely prevented operations. On the 5th, a thunderstorm hovered over the Dūn all day and made reception difficult at night. On the 6th though cloudless at the time of observation, storms preceded and followed the signals very few of which were received. It was curious, however, that on the 8th though a continuous stream of atmospherics was received, the wireless signals were exceptionally clear and could be heard without effort above the atmospherics, while on the following day and night atmospherics had ceased altogether. Between Jun. 10th and Aug. 25th signals were sent every Monday and Thursday and on most nights from 30 to 90 signals out of a total of 90 were received, even when monsoon weather prevented the observation of stars. Again in the Suget Karaul Series, from August 25th to September 1st, almost every signal was distinctly heard though those on August 25th to 28th were somewhat interrupted by atmospherics, the weather being very stormy. The conclusion to be drawn from these observations is that even throughout the monsoon there is every chance of a sufficient break in monsoon atmospherics to make reception of signals at least twice a week probable.

Results.—The nights on which both wireless and star observations were successful at both stations are as follows:

Skārdu, 1st set	1913, December 5th, 15th.
Skārdu, 2nd set	1914, February 5th, 9th, 10th, 11th, 12th.
Kargil	" February 25th, 26th, 27th.
Lamayuru	" March 11th, 12th, 13th, 14th, 16th.
Leh	" March 25th, 26th, 27th, 28th, 30th, 31st, April 1st.
Depsang	" June 5th, 8th, 9th.
Suget Karaul	" August 29th, 31st, September 1st.
Yārkand	Particulars not known yet.
Kashgar	Ditto.

Up to the present we have only heard of the general success at Kashgar and Yārkand. Operations at Dehra were successful on most nights.

The deduced longitudes are as follows:

Skārdu,	1st set	75° 38′ 24″·60,	weight 1
"	2nd set	" " 22 ·20,	weight 3
Skārdu, final result		75° 38′ 22″·80	
Kargil		76 7 40 ·65	
Lamayuru		76 46 32 ·01	
Leh		77 34 53 ·78	

Cav. de Filippi has not yet sent descriptions of his actual stations of observation; nor have the results of the observations at Depsang, Suget Karaul,

Yārkand and Kashgar been received. He has announced by wire the general success of observations at all these stations. It is accordingly certain that the longitude of these places merely requires to be worked out from the data already acquired.

It will now be possible to adjust the work of previous explorers in Central Asia to the more accurate longitudes just obtained.

It is to be hoped, now that a start has been made with this work, that further longitude arcs will be measured in India. The method has distinct advantages over that of employing wire telegraphy, the greatest perhaps being that work can be done away from a telegraph office. It is usually very difficult to bring up accurate triangulation to a telegraph office (*vide* G.T.S. Volume XVIII, Appendix No. 5) and failing this the results found by longitudes cannot be applied to the azimuths found by triangulation. This is the best method of freeing the triangulation from accumulated azimuthal error, and has an importance that does not appear to have been fully recognized.

IV.—Workshops.

Trestle for geodetic triangulation in wooded country (*vide illustration on opposite page*).—The trestle illustrated consists of twelve sections, each five feet high. It has been erected by hoisting the whole in a vertical position, and adding section by section underneath. This process is illustrated in the photographs, in which may be seen the four guy wires which emanate at the same rate from a four-grooved wheel, and other details. These wires keep the trestle vertical. In the first place about four sections may be joined together on the ground and then pulled up into a vertical position. When this is done the platform may be added without difficulty at the moderate height of 20 feet. After this the other sections are added one by one from below until the required height is obtained, all work being done on the ground.

In the design special attention has been given to lightness and portability. The wooden members are all five feet long, and the iron angle pieces are held in contact with them merely by the weight of the trestle and the tension of the tie-rods. This leaves the wooden members without projecting pieces, and accordingly convenient for packing up. They are also all interchangeable. Successive sections can be added until the necessary height has been obtained.

The length of the longest members and some other particulars are as below:—

Four legs of lifting gear	$10\frac{1}{4}$	feet.
Six pieces of T-iron in platform	8	,,
Eight pieces of L-iron rail round platform	8	,,
Total weight of trestle for a height of 60 feet	2,000	lbs.
Additional weight per 5 feet	130	,,
Lifting gear and derrick	300	,,
Height from ground level to platform	61	feet.
Height to theodolite axis	66	,,
Height to top of tent	70	,,

The platform is 8 feet square.

The whole trestle can accordingly be carried on bullock carts or camels, and the total weight is about one ton.

Access to the top is obtained by means of a ladder formed by a series of rungs strung on two wires, which can be rolled up for transit.

The theodolite is placed on a table which is mounted on gimbals, and the level of this table is controlled by four wires reaching to the base of the trestle. By this means permanent dislevelment of the instrument, due to movements of the trestle, is prevented. By balancing the instrument and its table, that is by arranging that the centre of gravity of the whole lies in the same horizontal plane as the gimbal bearings, oscillations of the instrument are largely avoided.

It was found in the early trials that when the observer moved, though the level remained satisfactorily constant, a change in azimuthal angle occurred, due to the change in loading of the trestle and a consequent skewing round. To overcome this the platform was also mounted on gimbals and controlled by four wires to ground level. By this means the loading of the trestle remains central and the non-central strains are taken up by the wires.

A few angles have been measured with a twelve-inch theodolite mounted on the trestle. It is found that an unfavourable time for observing occurs as the sun gains power a few hours after rising, and the effect is to cause changes of both level and azimuth. After the trestle is properly heated up these changes cease; and measures of angles in the afternoon have given very satisfactory results. Thus on 13th May 1915, between 5-40 and 6-40 P.M., ten measures of an angle were made giving the mean value 26°55′ 48″·4. The seconds of the individual angles were 51·0, 47·6, 48·4, 48·9, 46·2, 48·7, 50·5, 47·7, 48·3, and 47·0, giving a probable error of 1″ per observation. This seems to show that with proper precautions observations may be made of very nearly as high quality as can be made from a station at ground level.

Other special work.—Two auto-transformers and two detectors have been made for the wireless work.

Two break-circuits for the clocks of the pattern brought out by Lieutenant-Colonel G. P. Lenox-Conyngham have been made and fitted to the two extra standard clocks.

An instrument for calculating the effect of the attraction of mountain chains of any section has been designed and made.

A "versine staff" for reading the corrections to chained lengths due to slope of ground, designed by Major E. A. Tandy, was made in experimental form.

Operations in the workshops are much handicapped by lack of room and equipment. Most of the work has to be done in the open, which is very troublesome in rainy weather. No power is at present available and the handling of materials is difficult on that account. A scheme for a new workshop, which will remove these difficulties, is at present before the Government of India. It also deals with the pressing need for more accommodation in the type-printing office, in which work has doubled during the last 15 years.

V.—The Omori Seismograph.

The details of earthquakes recorded during the past year are given below. These have a new interest in view of their effect on the clock-rate as shown in Fig. 2.

Information published in the Daily Weather Report regarding the earthquakes recorded at Simla has been included for convenience of reference.

1913-14.

No.	Date.	Time of Beginning. Dehra.		Time of Beginning. Simla.		Duration in minutes.	Distance of Epicentre in Miles. Dehra.	Distance of Epicentre in Miles. Simla.	Intensity.	Remarks.
		h.	m.	h.	m.					
1	12th October 1913	14	49	14	49	62	5,250	5,000	Moderate.	
2	15th „ „	13	55	13	57	75	2,870	3,000	Do.	
3	15th November 1913	2	31	2	31	30	1,300	1,500	Slight.	
4	1st December 1913	22	58½	22	58	8	600	600	Do.	
5	16th „ „	1	45½	...		...	Local	...	Do.	
6	21st „ „	21	13	22	44	60	1,600	...	Moderate.	
7	5th January 1914	9	33	9	31	6	350	300	Slight.	

1913-14—(*continued*).

No.	Date.	Time of beginning. Dehra.	Time of beginning. Simla.	Duration in minutes.	Distance of epicentre in miles. Dehra.	Distance of epicentre in miles. Simla.	Intensity.	Remarks.
		h. m.	h. m.					
8	12th January 1914	15 13	...	49	2,380	...	Moderate.	
9	7th February 1914	17 15	17 15	25	840	750	Do.	
10	13th „ „	...	15 42	...	...	450	Slight.	
11	26th „ „	10 48	10 47	85	5,320	4,000	Moderate	Definite.
12	7th March 1914	0 54	0 54	52	3,800	4,000	...	Doubtful.
13	15th „ „	1 39	1 39	58	4,300	2,500	Moderate	Japan earthquake.
14	18th „ „	10 10	10 9	48	4,300	4,000	Do.	
15	18th „ „	12 7	12 6	42	4,200	4,000	Slight.	
16	28th „ „	16 16½	16 19	47	1,100	1,300	Moderate	Definite.
17	30th „ „	6 34½	6 33	115	12,700	11,000	Slight.	
18	30th „ „	...	1 20	...	...	Local	Very slight.	
19	31st „ „	17 36½	17 37	10	150	150	Slight	Definite.
20	8th April 1914	6 12½	6 12	13	350	300	Do.	Definite.
21	11th „ „	22 14	82 18	124	...	...	Moderate.	
22	18th „ „	5 8	5 8	7	100	...	Very slight.	
23	26th „ „	2 7½	2 8	8	210	300	Slight.	
24	29th „ „	11 31	11 30	13	910	1,000	Do.	
25	1st May 1914	3 48	3 48	6½	175	100	Do.	
26	22nd „ „	13 58½	13 58	22	1,050	600	Slight to moderate.	
27	27th „ „	20 3½	20 4	130	4,270	4,000	Great.	
28	30th „ „	10 24	10 24	84	2,800	3,500	Moderate.	
29	12th June 1914		6 44	...	...	100	Slight.	
30	21st „ „	13 5	13 5	84	4,480	6,000	Moderate.	
31	26th „ „	0 45	0 45	100	2,800	2,000	Great.	
32	5th August 1914	4 14½	4 15	90	1,400	1,300	Moderate.	
33	6th „ „	9 56	9 55	30	87	100	Slight.	

It is to be noticed from this table and the corresponding one for the previous season (*vide* Rec. Vol. V, p. 147) that more than half the recorded earthquakes occurred in the months March to June, and more than one-third in March and April. The numbers for each month beginning with January are as follows: 4, 5, 13, 9, 6, 5, 1, 6, 3, 2, 4, 5.

PART III.—SPECIAL REPORTS.

PHOTO-LITHO OFFICE, CALCUTTA.

BY CAPTAIN S. W. S. HAMILTON, R.E.

There has been a decrease in departmental work due, in part, to the number of 1-inch standard sheets in colours received for publication being considerably less than in 1912-13. The outturn of extra-departmental work, however, shows a marked increase, and this has enabled the Office to show an increase in the total number of maps printed during the year.

1-inch standard sheets.—The total number of 1-inch standard sheets in colours is 158. In addition, five 1-inch standard sheets in colours were reprinted to replenish stock, while of preliminary and provisional editions, 8 sheets were printed in black and brown and 41 sheets in black only. These together bring the total number of sheets printed in modern form to two hundred and twelve, a decrease of 40 sheets as against 1912-13, but maintaining an increase of 24 sheets as compared with 1911-12.

Carried forward to 1914-15 there remain, of 1-inch standard sheets in colours, 9 for preliminary proofs, and 7 for proofs with shade before the issue of press order, 31 proofs despatched and awaiting the return of colour guides, and 5 with press order in Photo. and 7 in Litho. Branch; there are also 3 press orders stopped. Of preliminary editions the number in hand is 18.

Arrears.—Exclusive of 1-inch standard, degree and 1-M sheets, there are 8 departmental press orders as against 12 remaining over in 1913, and 112 printings of extra-departmental work to be undertaken as against 155 on the corresponding date of that year.

Layered maps.—Further progress has been made and experience gained in the manner and method of printing layered maps.

The introduction of layered maps in the last two years has largely increased the number of plates that have to be gummed out for the transfer of tints.

The first specimens were printed with the successive layers falling over the blue of double lined rivers and when this defect was remedied great difficulty was found in registration.

This has been got over by making two contour helio. plates. To one of these the complete outline plate is transferred by a set-off, blue areas being filled in 'solid' and from this all sets-off for the layer plates of the map are made. This is called the key plate. The other contour helio. is used for printing.

On the actual layer plates themselves, where one or more different tints have to be transferred, the contours defining the limits of successive layers are lightly cut in with a pricker. The set-off required for a guide to the preparation of the second, third, or subsequent layers is washed off after the transfer of each of the earlier tints, and if this pricking were not done, the definition of the limits would therefore be lost.

This necessitates extra labour but in the absence of a good permanent set-off powder, it remains the only available method.

The manner of etching successive layer plates in relief, introduced in 1912-13, has been modified and it is now found more advantageous to etch the first layers only in relief on a polished plate and the layers on successive plates in the ordinary way. Among the most important undertakings of the office have been the 32-mile layered map of India in 12 sheets and sheet No. N-43 E., of the International layered map of the world, which latter is also the first engraved map with separate engraved plates for each colour produced by the Department. Hitherto, in all layered maps printed by the Department the first and succeeding browns and reds have been carried up through all successive altitudes to the highest layer. This has been done to assist the gradation but has resulted in a lack of clearness in the colouring of the top layers. The international

map, however, follows a different method whereby a wider series of colours are used to obtain the desired effect and each successive colour in the ascending layers overlaps two layers only, with the result that the final map is much cleaner and more luminous.

Following this method, experiments are now in progress with sheet 7 of the 32-mile layered map of India, and should it prove successful, of which there is every hope, it will be extended to the other sheets of the 32-mile map and adopted generally. In addition to the two maps named above, four layered maps have been printed during the year on the $\frac{1}{2M}$ scale, four on the $\frac{1}{M}$ scale and ten Degree Sheets, while, as an experiment, one one-inch standard sheet was printed with five hundred foot layer intervals in monochrome.

The number of layered maps in hand in the office at the close of the survey year is five.

Impressions.—The total number of impressions pulled is 22,86,845, an increase of 3,20,387 over the previous outturn of 19,66,458 in 1912-13, itself an increase of 4,01,962 over the preceding year.

Negatives.—The output of negatives for the past three years, with the cost per 100 square inches is as follows: –

YEAR.	Number of negatives.	Area in square inches.	Cost of chemicals per 100 sq. inches.
			Rs. A. P.
1911-12	3,882	21,57,820	0 4 11
1912-13	4,123	22,71,971	0 5 11
1913-14	3,547	18,78,098	0 5 11

The decrease is due, in part, to the decrease in the number of standard one-inch sheets submitted for reproduction and, to a small extent, to a gradually increasing use and knowledge of the advantages and capabilities of the Vandyke process by officers other than those of the Department. In any consideration of the annual comparative outturns of the Photo and Litho branches it should be remembered that the preparation of a layer plate is entirely a lithographic operation.

Half-tone shading.—There has been a very large increase in the number of originals received for reproduction of half-tone hill shading, the number of negatives having increased from 53 in 1911-12 and 42 in 1912-13 to 153 during the year under report.

A New Lens.—The new 1700 mm. Zeiss Approchromat Planar Lens and Prism ordered in November 1906 and received in Calcutta in March 1912 have now had full trial.

The lens was intended for use on No. 1 Camera (42″ × 28″), but on receipt, it was found that the great weight of the lens and prism (about 90 lbs.) accentuated the vibration to which this camera had always been liable. As it would have been unfair to the makers to test it on a shaky camera against other lenses mounted on rigid cameras and stands, it was decided to keep the test pending conversion of No. 1 Camera to the Precision or all-metal base type. An order was accordingly placed with the Mathematical Instrument Office to have this done. As the Mathematical Instrument Office estimated the approximate weight of the converted camera at nearly three tons, this necessitated strengthening the studio floor. This was completed in 1913 by inserting two long H girders which form a base for the rails on which the camera runs.

When the lens was brought into use it was found to be thoroughly satisfactory in every way. It covers the largest plate in use (46½″ × 33″) with ease and gives excellent definition and even illumination over the whole plate. If stopped down it would probably cover 50″ × 40″.

A comparative test of the "Planar" and "Cooke" lenses under exactly the same conditions was, if anything, in favour of the "Planar." Considering the superior covering power of the "Planar" and that the "Cooke" is universally admitted to be the best English-made lens for this class of work, the result should be considered very satisfactory. The fact that the lens is an approchromat, that is to say, corrected for all rays, is important, for this means that no matter what changes or improvements take place in photographic practice, the lens will always give equally good results.

Owing to the superior covering power of the "Plānar" and the possibility of using fairly large apertures for ordinary work, No. 1 Camera can easily turn out 15 % to 20 % more work than it could with the old lens. (Zeiss 1310 mm. "Protar").

To give an accurate comparison of the cost of outturn by the old and the new lenses is a difficult matter. The old lens was required to do much the same class of work as that on which the new Zeiss lens is now employed, but for very large negatives, it had to be very much stopped down and its definition at the corners of work was extremely poor while that of the new lens has invariably given excellent results.

This difficulty with the old lens meant the employment of specially skilled labour and a great deal of trouble, whereas the excellence of the new lens and the complete apparatus has now made it possible to obtain vastly superior results with a minimum of trouble and a less need for expert knowledge, thus making it possible for all work on the camera to be exclusively conducted by members of the 3rd Division without fear of its being spoilt.

A special lens for correcting distortion.—The Officer in charge has designed a new semi-cylindrical lens to be used in conjunction with the ordinary lenses employed on the cameras and fitted to the half-tone screen carrier. This new lens is on the principle of the barrel lens in use with the spectroscope and enables the camera to correct distortion in both dimensions, the condition however, being that the distortion should be equal throughout the length of any graticule in which it occurs.

It is not intended for use with maps but with plane-table sections of which print enlargements or reductions only are required, as the definition is slightly impaired, but it now enables any of the latter, except those with the most unusual distortion, to have their graticule dimensions brought within the correct limits. Experiment has proved that the correction is apportioned equally throughout the whole area of the copy of the plan-board, and as an example of the capabilities of the lens, a plan measuring $5\frac{1}{8}$th inches in one dimension and $4\frac{7}{8}$th inches in the other has been corrected to produce a negative measuring 5 inches in each dimension.

The lens made is capable of dealing with a plan of the size of 5-minute squares on the scale of one and-a-half inches to one mile. Larger glasses, curved to required measurements, were indented for from England and have now been received. The new lens, now in process of making, will cover six 5-minute squares on the scale of one and-a-half inches to one mile. Plane-table Sections covering a whole standard sheet can be dealt with in two sections.

New prescriptions.—The preparation known as photo-pake is now mixed with Carbolic Acid and Glycerine in the following proportions:—

Photo-pake	20 ozs.
Carbolic Acid	1 oz.
Glycerine	1 oz.

This was introduced to prevent the original preparation being eaten off the negatives by white-ants and is found satisfactory.

A small change has also been made in the sensitizing solution used in the preparation of helio plates, Ammonium Carbonate having been substituted for liquor Ammonia in October 1913.

Y

The solution is now made up as follows:—

Dry Egg Albumen	150 gms.
Ammonium bichromate	60 „
Potassium „	30 „
Water	3,000 c.c.
Ammonium carbonate	60 gms.
Alcohol	60 c.c.

Minor improvements.—No other change has been made in the methods and formulæ in the Photo branch but it is of interest to note that, for the first time in the office, the system has been adopted of the interchange of men employed on "duffing out" in the retouching section and on "gumming out" in the Litho-drawing Section as expediency demanded and this has greatly facilitated the rapid and expeditious outturn of urgent work.

Mr. Taylor, Photo Manager, also made a very ingenious temporary conversion of the Centurette printing machine which is used for half tone and line work into a rubber offset "perfecting" machine and thus enabling both sides of ruled paper to be printed in the one operation, ensuring exact register of lines on one side of the paper with those on the other, a most desirable object where the paper used is very thin and transparent and lines have to be printed on both sides of it.

Rubber offset printing.—Captain Sackville Hamilton, the officer in charge of the Photo-Litho Office, has made a careful investigation into the subject of rubber offset printing at Calcutta. The results have failed to show that the quality of impressions from rubber on good printing paper are superior to those obtained from zinc, although rubber offset printing undoubtedly enables better impressions to be obtained on rough paper than are obtained from zinc.

A full report on the investigation into Rubber Offset Printing appears as Departmental Paper No. 8.

New etching machine.—A new "Levy," acid blast, etching machine to etch plates 27″ by 24″, for use with either nitric acid or perchloride of iron is on order and is shortly expected from England.

The machine is guaranteed to etch a flat tint of the above size perfectly even and should prove a great boon to the office.*

New printing machines.—One additional double-demy flat-bed printing machine has been received from England and is now in process of erection, while one quad crown and one quad demy machine are on order from Messrs. Mann & Co., and it is hoped that both will be received and erected in 1915, the latter at the beginning and the former towards the end of the year.

The Director-General of Stores in England has been asked to have these machines provided with geared riders, as, owing to the large amount of ink which it is necessary for the rollers to carry when printing layered maps, where large areas are required in one colour, and to the consequent stiffening of the ink which takes place, due to the inability to take up sufficient water, it is found that the rollers are affected by the backward and forward movement of the plate fixed to the bed of the machine and do not turn with perfect regularity in their seatings but slip round at intervals in uneven movements thus causing streaks of varying qualities of colour to appear on the printed layer.

This is especially the case where one layer has to be printed over another but is hardly noticeable with small areas.

Hitherto, the difficulty has been overcome by the device of laying a strip of ink of the same consistency as that on the rollers along the exterior edges of the plate outside the margins of the map being printed, and has served its purpose, but it can only be described as a makeshift.

New graining machines.—An indent has also been submitted for two new graining machines.

* Since this was written the machine has been lost in the *S. S. Chilkana* sunk by the German Cruiser *Emden* and another has had to be ordered.

These are of the Southampton pattern and are to replace those designed by Mr. S. M. Coard as it is found that the circular flat motion of the former gives a grain to the plate superior to that given by the tilting motion of the latter machine.

Pamphlets.—During the year under report, the Photo-Litho Office has issued a pamphlet on the Reproduction of Maps, Plans, Photographs, Diagrams and Line Illustrations, containing much valuable information in a concise form and 15 illustrations descriptive of the methods of preparing originals for reproduction. This pamphlet is proving of considerable use to those for whom it was issued and of very appreciable benefit to those who have to deal with the work of reproduction.

Major Hedley's pamphlet entitled "Notes on the organisation, methods and processes of the Photo-Litho Office" has been entirely revised and much amplified, especially with regard to the photographic and lithographic formulæ contained in the appendices, and is now at press.

REPORT OF THE GOVERNMENT COMMITTEE ON THE MAGNETIC SURVEY OF INDIA.

At the suggestion of the Surveyor-General, a Committee was assembled by the Government of India in March 1914, to consider the present position of the Magnetic Survey and advise as to the steps to be taken to complete it.

The Committee consisted of:

President.

DR. G. T. WALKER, C.S.I., Sc.D., F.R.S.

Members.

CAPTAIN R. H. THOMAS, R.E.

MR. J. DE GRAAFF HUNTER, M.A.

The conclusions arrived at are contained in the following pages.

The matters discussed by the Committee may be conveniently divided as follows:—

1. Methods of reduction—
   (*a*) Corrections for diurnal variation.
   (*b*) „ „ secular variation.
2. What elements should be published?
3. Selection of Epoch.
4. Whether the field work of the first general magnetic survey is complete.
5. Whether regional disturbances should be tabulated, and if so, by what method.
6. What detailed magnetic surveys are now desirable?
7. The interpretation of regional disturbances in relation to geophysical features.
8. The length of time before the results of the present survey can be published.
9. How long should Government maintain—
   (*a*) base stations,
   (*b*) repeat stations?

   At what date should the second general magnetic survey be commenced?
10. The desirability of another comparison of the absolute instruments with Europe.

1. *The methods of reduction.*

It is usually assumed that the method of reduction of field observations consists in applying three corrections:—

(*a*) for normal diurnal variation.
(*b*) for short lived disturbances.
(*c*) for secular variation.

For the purposes of the survey, in order to save computing, it has been until 1912 the practice to derive the average diurnal variation of each month from five quiet days selected in such a manner that their "centre of mean position" coincides closely with the middle day of the month. The means of the

readings derived from the magnetographs on the quiet days at the hours 0, 1, 2, 3,......22, 23 are tabulated and their mean is taken as the mean value for the month, while the departure from this mean of the values at the hours 0, 1, 2,......22, 23 are taken as giving the normal daily variation for the middle of the month: at other times the daily variations are obtained by interpolation between the values of two successive means. The diurnal variation at a place is a function of the local time there, and when applying the correction for diurnal variation to an observation at a field station at a definite hour by local time the obvious way of deriving it is by interpolation from the values of the nearest observatories each at the same local time.

In order to calculate the disturbance (*b*) at any time the undisturbed value has first to be calculated. This is derived from the mean of the month by applying the diurnal variation appropriate to the date, and the difference from this hypothetical undisturbed value is taken as the disturbance. It will be noticed that in this method of procedure any change produced by secular change between the day in question and the middle of the month has been included in the disturbance.

It is generally supposed that since big disturbances occur almost simultaneously over the earth, the smaller disturbances, that are shown on days which are quiet enough for reliable field work, also occur simultaneously over India, and the obvious way to correct for them at a field station is to interpolate between the disturbances occurring simultaneously at the observatories. It is, however, not certain that a part of the disturbance is not a function of local time.

The correction (*c*) for secular variation reduces the observation from the date on which it is made to the epoch selected.

It has frequently been assumed that this correction is strictly proportional to the length of time involved, but in India this assumption is not justified. The inequalities caused by annual variation and by irregularities may together amount to as much as $1'{\cdot}3$ in Declination, 45γ in Horizontal Force, and $8'$ in Dip; such quantities are too large to be ignored.

If the monthly means of an element at the different observatories are plotted it will be seen that disturbances extending over one or two months affect the whole country by roughly similar amounts, and that this applies to a less extent to disturbances lasting over several years.* Thus in each case, if the value at a field station is wanted, interpolation is inevitable.

The plotted monthly means of the observatories for each element lie fairly closely upon a pair of straight lines extending from 1903·0 to 1909·0 and 1909·0 to 1914·0 respectively. For the repeat stations† similar pairs of lines have been drawn and the annual change for each of the two periods plotted on a map of India. The consistency on the map is fairly good and the rate of secular change for a field station can be derived with an accuracy which will be discussed later on.

Thus in order to reduce from the value of an element observed at a field station to its value at the epoch we have to apply corrections for normal diurnal variation, disturbance, and for uniform secular variation, on which are superposed irregularities of one or two months, as well as irregularities of several years.

Of these five corrections that for uniform secular change can scarcely be modified; but the question arises whether the remaining four cannot be simplified, and an affirmative reply seems possible.

Let us consider a field observation, say of declination, at a particular hour on a particular day, and suppose that we have the corresponding magnetograph curve of declination at one of the observatories. Let us subtract the declination at the hour in question as tabulated from the chart from the value at the middle of the month on the chart of uniform secular variation for that observatory. This difference is the correction that has to be applied to the value at the

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* Such disturbances might also be called irregularities in the march of secular variation.

† Any field station at which several observations have been made should also be utilised.

observatory at the hour of the field observation in order to give the value at the middle of the month ; and if corresponding differences be tabulated for all the observatories the value to be applied at the field station may be obtained by interpolation. That this is so follows from the fact that the difference is made up of four parts which can each be obtained by interpolation. It may be objected that interpolation cannot be effected by the same process for normal diurnal variation and also for disturbance, inasmuch as the first has to be interpolated from observatory values at the same local time and the second at the same absolute time. It is easily seen, however, that if the disturbance causes no marked discontinuities in the curve, the error introduced by interpolation at the same local hour is very small, while if there are marked discontinuities the field observations are of doubtful value ; and it may also be verified that if the interpolation be made from simultaneous readings at the observatories the error introduced into the normal diurnal variation is very slight.* The latter method of interpolation seems on the whole more satisfactory and has been adopted. In practice it seems better instead of effecting the interpolations by assuming a different weighting of the observatories for each field station to divide the country into areas over each of which the corrections may be treated as constant, the areas† being sufficiently numerous to make certain that the error in the correction at places on its boundary shall not be too large.

Declination.—In declination, the correction for normal daily variation will not exceed 4′ ; and the correction interpolated in the ordinary manner from the base stations can at the same local time be relied on to 0′·2 while if the 14 areas be used the maximum error is 0′·3, the average being 0′·15. Practically no irregular disturbances are big enough to cause the rejection of observations; the error introduced is never more than 0′·5 and is in general about 0′·3. It appears that the annual secular changes can be derived to within an average accuracy of about 0′·25 per annum in the first period (1903·0 to 1909·0) and 0′·3 in the second period (1909·0 to 1914·0), the extreme errors being probably 0′·4 and 0′·5 respectively ; thus the average error in the average period for which the correction has to be applied is about 1′·0 and the maximum error in the longest period 2′·4. The error due to interpolating for the departure of the curve of secular change from a straight line is estimated at 0′·3 on the average and 1′·0 in the outer limit. The value of declination for a particular station at the epoch is thus affected by errors of the following approximate amounts :—

	Average.	Extreme.
Of observation	0′·2	0′·3
Reduction for diurnal variation‡	0′·2	0′·5
Reduction for disturbance‡	0′·3	0′·5
Reduction for secular variation :—		
(1) from error in annual change	1′·0	2′·4
(2) from departure of the curve of secular change from a straight line	0′·3	1′·0
Final Value	1′·1	4′·7

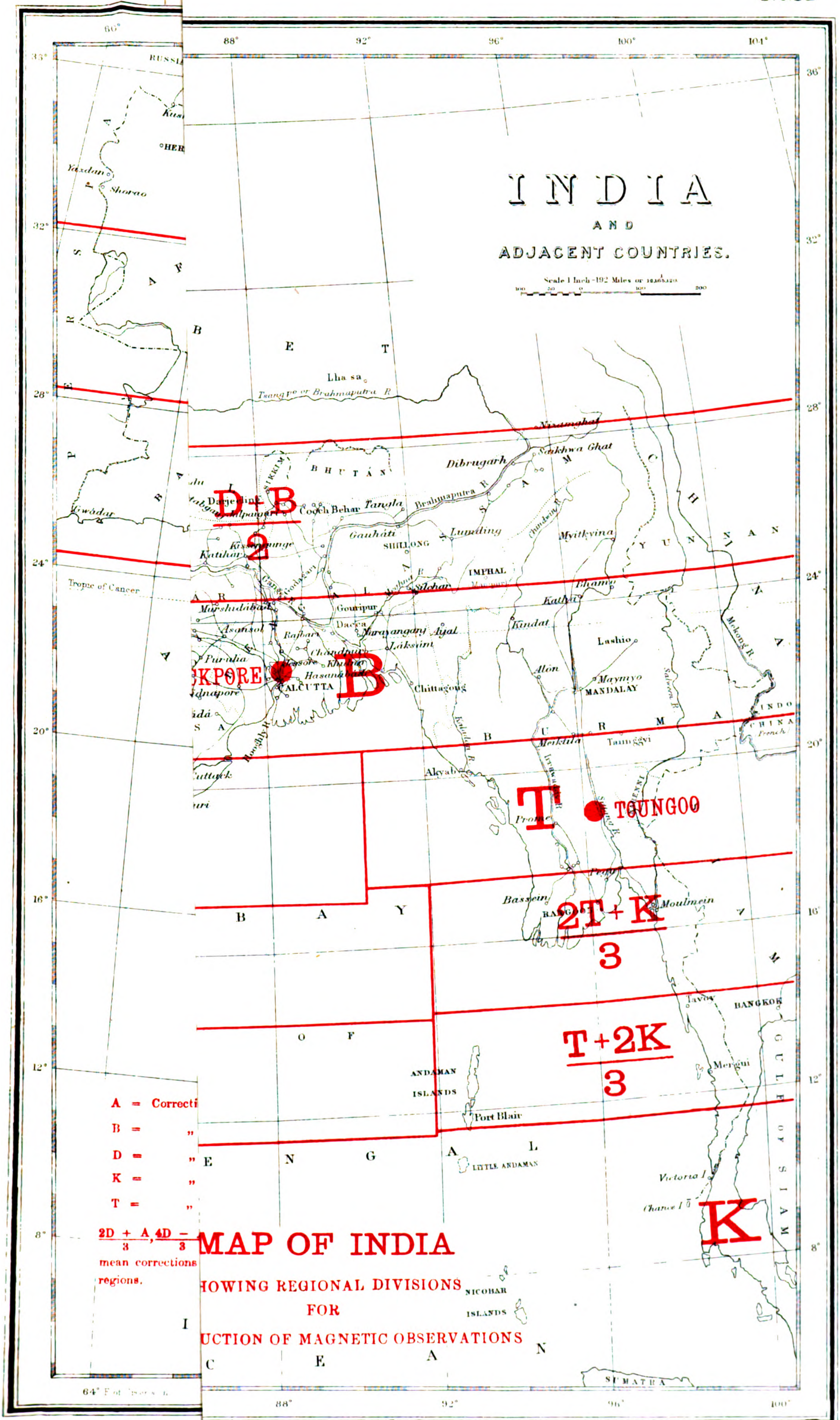
Horizontal Force.—In horizontal force, the biggest correction for normal daily variation in years of maximum sunspots, may be taken as varying from 20γ in Northern India to 95γ in Southern India ; and the correction interpolated from the base stations at the same local time can probably in the worst cases be relied upon to 20γ while in general the error will be materially less. The corrections for disturbance are of practically the same accuracy. The secular variation in a year can be estimated from the charts with an average error of about 2γ and an extreme error of about 4γ.

* Its value is shown in the following table :—

	Average.	Extreme.
Declination	0′·1	0′·2
Horizontal Force	1γ	2γ
Dip	0′·1	0′·2

† On the information before us we would suggest 14 areas as indicated on the sketch map appended.

‡ Assuming 14 areas.


INDIA
AND
ADJACENT COUNTRIES.
Scale 1 Inch = 192 Miles
D+B
2
B
T
TOUNGOO
2T+K
3
T+2K
3
K
KPORE
A = Correcti
B = "
D = "
K = "
T = "
2D + A, 4D −
3 3
mean corrections
regions.
MAP OF INDIA
HOWING REGIONAL DIVISIONS
FOR
UCTION OF MAGNETIC OBSERVATIONS
Lhasa
Tsangpo or Brahmaputra R.
BHUTAN
Dibrugarh
Darjeeling
Cooch Behar
Gauhati
SHILLONG
Lumding
IMPHAL
Silchar
Murshidabad
Dacca
Asansol
CALCUTTA
Chittagong
Akyab
Prome
Bassein
Moulmein
Mandalay
Lashio
Bhamo
Myitkyina
Tavoy
BANGKOK
Mergui
ANDAMAN ISLANDS
Port Blair
LITTLE ANDAMAN
NICOBAR ISLANDS
SUMATRA
B A Y O F B E N G A L
GULF OF SIAM
Tropic of Cancer

The value of Horizontal Force for a particular station at the epoch is thus affected by errors of the following amounts* :—

	Average.	Extreme.
Of observation	5γ	12γ
Reduction for diurnal variation	5γ	22γ
Reduction for disturbances	5γ	20γ
Reduction for secular variation :—		
(1) from error in annual change	6γ	25γ
(2) from departure of the curve of secular change from a straight line	4γ	10γ
Final Value	12γ	89γ

Dip.—In dip the average and extreme errors of observation may be taken as 1′·0 and 3′·0 ; the largest correction for normal daily variation is 3′·0 and the correction interpolated from the base stations can be relied upon to 0′·2 in the worst cases or 0′·1 on the average.

In secular variation the same method has been adopted as for declination, the curve for the variation being replaced with sufficient accuracy by two straight lines meeting at 1909. The errors involved† are shown on the following table :—

	Average.	Extreme.
Of observation	1′·0	3′·0
Reduction for diurnal variation	0′·1	0′·4
Reduction for disturbance	0′·2	0′·5
Reduction for secular variation :—		
(1) from error in annual change	1′·0	3′·5
(2) from departure of the curve of secular change from a straight line	0′·5	1′·7
Final Value	1′·5	9′·1

For the purpose of reducing field observations to a fixed epoch we have given a method of dealing with all corrections which arise by means of interpolation and have also made estimates of the average and extreme errors which may be introduced by the application of this method. The corrections involved, apart from those for secular variation, may be considered small in relation to station error: but as these have all been dealt with together, it appears that the full correction involves no more labour than a portion of it: the method is justified unless the magnitude of the full correction is too small.

In order to examine this it is only necessary to take the maximum corrections given by the observatories during the ordinary working hours (7-18) and months (November-May) at a time of maximum sunspots.

Diurnal Variation.

	Dehra Dūn.	Barrackpore.	Kodaikānal.	Toungoo.
Declination	3′·8	3′·3	1′·8	2′·4
H.F.	23γ	40γ	92γ	46γ
Dip‡	2′·3	2′·5	2′·7	2′·6

The magnitude of storms which are not sufficiently great to cause the rejection of observations may be taken as much the same as that of the diurnal changes indicated above; and hence the total correction under examination may be taken as having maximum values in declination of about 8′, in horizontal force 180γ and in dip 6′. It appears to us that these magnitudes are so large in comparison with those that may arise from secular variation that the method proposed should be followed in full.

* These figures are provisional inasmuch as the data on which they are based are in general not corrected for disturbances at the time of observation ; thus they provide outside limits for the errors.

† The data have not as yet been corrected at all; hence the above errors are probably in excess of what will ultimately be found correct.

‡ The dip observations are for 1908-09, the first year for which observations are available.

We are of opinion that Declination and Dip should be published to the nearest minute and Horizontal Force to the nearest 10γ.

2. What elements should be published?

We think that at the field stations, Declination, Horizontal Force, and Dip should be published, as corrected for the date and also as corrected to the Epoch. In the latter case the rectangular components also should be published, because of their convenience for purposes of investigation. The charts should give Declination, Horizontal Force, Dip, and the three rectangular components.

We also think that the tables and charts of the monthly mean values of the various elements at the observatories should be published.

3. The Selection of the Epoch.

We consider that 1st January 1909 should be adopted as the Epoch, one reason being that this date gives the least value for the extreme errors of the magnetic elements, and another that this is the natural meeting point of the two lines which give the best approximation to the curves of secular change.

4. Whether the field work of the first general magnetic survey is complete.

The number of the field stations that have been occupied bears a satisfactorily large ratio to the area of India, and their distribution appears good over all accessible parts of the country. In estimating the quality of the work we have to consider that at the observatories and that in the field: the former appears to have been quite satisfactory. As secular corrections have not yet been worked out the opinion of the Committee regarding the field work must depend on the series of observations at the repeat stations, as examined for their secular variations. The only element for which these have been fully corrected is declination, and it is thus only from declination observations that an opinion can be formed. The impression left by these is that the field work also has been quite satisfactory.

We are, therefore, of opinion that unless the work in horizontal force or dip proves, for some reason of which there is at present no indication, to be less good than that in declination, the field work of the first general magnetic survey is complete.

5. Whether regional disturbances should be tabulated, and if so, by what method.

We are of opinion that the publication of the data as recommended in 2 will render all the essential facts accessible to investigators; and it seems likely that some years may elapse before this can be effected. Hence as the computation and discussion of disturbances would probably take at least a year and any unnecessary delay in publication is greatly to be deprecated, we think that the disturbances might be published later as a supplementary piece of research work.

It appears from a preliminary examination that terrestrial lines produced by a formula of the type $a + bl + c\lambda$ would be satisfactory; the labour involved would not be very large and could be undertaken by an officer who might be in charge of the base stations and of any observations at repeat stations that might be made for the purpose of keeping the survey up to date.

6. What detailed magnetic surveys are now desirable.

It appears to us open to question whether the detailed magnetic surveys carried out hitherto have proved worth their cost in time and money*; and in the case of India we think it likely that while the economic value would be

* In the case of Great Britain experience showed that the information regarding regional disturbances derived from a survey of 205 stations agreed in its 'delineation of the principal magnetic features' with that from a survey of 677 stations.

small, the scientific value would not be large enough to justify the expenditure of money that is much needed for other scientific purposes. In any case, however, it will not be possible to consider in what part of India intense or widespread disturbances are found until the charts of the elements have been prepared.

7. The interpretation of regional disturbances in relation to geophysical features.

The importance of a disturbance is probably limited to its geological or geodetic effects; and should it be decided to compute and publish the details of Indian disturbances it would presumably be desirable to arrange for the discussion to be carried out in collaboration with specialists in these subjects.

8. The length of time before the results of the present survey can be published.

We are of opinion that in spite of simplifications in the methods of reduction it cannot be expected that without an increase in the staff publication will be completed in less than three years from now. In view of the fact that the survey was begun in 1902 we think that, if any arrangement can without difficulty be made for accelerating the final work, this is desirable.

9. How long should Government maintain (a) base stations, (b) repeat stations? At what date should the second general magnetic survey be commenced?

The practice of other countries in regard to the repetition of surveys is extremely variable. In Great Britain the survey is to be brought up to date after 23 years; in the United States revisions after 5 or 10 years are at present regarded as desirable; but in France, Holland, South Africa, Japan and the Dutch East Indies it does not appear that a second survey has been carried out although in two cases intervals of 23 and 19 years have elapsed.

In the case of India it appears to us that economic considerations play extremely little part in this matter, and that it is for the sake of science alone that the survey will be repeated. Now for most theoretical questions the maintenance of observatories with continuously recording instruments appears of far greater importance than the execution of frequent surveys, and it seems to us that the needs of science will be satisfactorily met by bringing the survey up to date at the sunspot minimum of about 1935 or 1946* and by maintaining an adequate number of observatories in continuous operation. It will probably be found sufficient to observe in two successive years at all the present repeat stations† and to make comparatively few observations at field stations except in disturbed areas. If for any special reason a survey is desired at an earlier date the acceptance of these proposals will not prevent this from being done.‡

The maintenance of the observatories will make it possible to give an approximate reply to any queries regarding the magnetic elements at any time at any place in India by interpolating for secular change; and as Toungoo, Kodaikānal and Dehra Dūn form an outlying triangle it will presumably suffice if these are maintained; we are, therefore, of opinion that Barrackpore might be closed without serious loss.

It will be remembered that the maintenance of Alībāg is independent of the Magnetic Survey of India.

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* In a letter to Lieutenant-Colonel Lenox-Conyngham, Dr. Chree expresses the impression that the interval in India between two surveys should be not less than 20 years, and suggests "33 as practically three average sunspot periods and a third of a century."

† These should be marked in a permanent manner and handed over to the care of the local authorities so that there shall be no question as to their exact position.

‡ One objection to the above proposal is that on the one-inch maps of the Survey of India it is customary to give the declination to the nearest five minutes; and if the published figures are to be really accurate it will be necessary to observe declination at the repeat stations at intervals of five years. If however declination were given to the nearest half degree it would suffice if the interval were ten years.

10. *Desirability of another comparison of the absolute instruments with Europe.*

The intercomparisons of magnetic instruments made by various investigators have shown that considerable differences may exist between the determination of the magnetic elements by various observatory and magnetic survey instruments; these discrepancies frequently largely exceed errors of observation.

It is therefore desirable that the published values of the magnetic elements should be reduced to an international standard so far as this is possible.

The difference between the Indian Survey standard instrument and those of other countries in the determination of the Horizontal Intensity is at present somewhat uncertain, and we think that this should be redetermined at an early date.

GILBERT T. WALKER.

R. H. THOMAS.

J. DE GRAAFF HUNTER.

GEOGRAPHICAL SURVEYS, N. E. FRONTIER.

SURVEY OPERATIONS WITH THE AKĀ PROMENADE.

BY LIEUTENANT P. G. HUDDLESTON, R.E.

PERSONNEL.

Imperial Officers.

Lieutenant P. G. Huddleston, R.E.

Lower Subordinate Service.

2 Surveyors, etc.

Narrative.—The Akā Promenade originated in proposals for a short tour of two months' duration by Captain Nevill, the Political Officer of the Western Section of the North-East Frontier of Assam, to the Akā country.

The country had not been visited since the expedition in 1883-84.

It was hoped that unexplored country might be reached and, in consequence, it was decided that a Survey Officer and a native surveyor should accompany the Political Officer.

With the sanction of the Surveyor-General, preliminary arrangements for the survey were started about 20th October 1913, and were completed a month later at Tezpur.

Survey operations up to and over the first range of hills beyond the administrative border were carried out while preparations for the movement of the Political Officer were being made. Observations from two trigonometrical stations on this range, and detail survey up to about the same line, were completed by the end of December.

The collection of rations delayed the advance up the valley of the Bhareli River, and the commencement of the revision of previous survey in this direction, till about Christmas.

Meanwhile the visit to the Lower Subansiri River, which had originally been in the political cold weather programme, had been abandoned, and the time allotted to it was now assigned to an extension of the tour in the Akā country and neighbourhood.

Arrangements were now made to hold a second surveyor in reserve in Assam in case of emergencies. This man's services were subsequently made use of.

Between the end of December and middle of January the main body of the Promenade moved on to the Tenga River near Jamiri, whence Lieutenant Huddleston visited Dirang Dzong. During this visit he was able to form a connection with Captain Morshead's work to the north, and to fix the position of the watershead between the basins of the Towang Chu on the north and those of the Bichom and Digien streams on the south.

By the end of the month (January 1914) the main body of the Promenade with its rations had moved forward to a point on the Bichom River some 7 miles above its junction with the Tenga River.

From this point onwards it was split into two parties, one of which visited the Miji country up the Bichom River, while the other worked through the valley of the Kuvu stream and visited the Mīri Akās who inhabit it.

The former party, with which Lieutenant Huddleston went, got up as far as the Silung huts of Pointong, on the Upper Bichom, and the semi-Bhutia village of Bux on the Digien stream.

The latter, with which were the two native surveyors, got a few miles beyond the village of Yefan on the Upper Bhareli River, though not without encountering demonstrations of unfriendliness on the part of the Daflās inhabiting this part of the valley. These demonstrations did not, however, interfere with survey work till, on 8th and 9th of March, they culminated, in the neighbourhood of Riang, in open hostilities in which a number of Daflās were killed, and in punishment for which their village of Yefan was burnt.

The Promenade now (10th March) started back to Tezpur, and survey operations in the valley of the Bhareli River were practically ended.

Lieutenant Huddleston had been able to join the Eastern party a few days before its return, and had had an opportunity of checking the work done by the surveyors with it. From what he saw of the Bhareli River from the hills in the neighbourhood of Riang, he is of opinion that the source of the river is further to the north-west than is shewn on the old maps.

He now returned to Tezpur, and from there went across to Amatulla, in the foot hills. This place is on the Tibetan trade route, and is the winter quarters of the Talung Dzong Dzongpens, who control this end of the trade route. From here he was able to carry his survey up to the Bhutān border, and reached the Jhum La and Dengan passes.

He returned to Tezpur on 8th April, and survey operations were then over.

The last of the survey detachment reached Shillong on 15th April.

Between 8th March and 22nd April Captain Nevill made a tour through Dirang Dzong, and returned to India by the Udalguri trade route.

For political reasons a surveyor did not accompany him, nor was this needed from a survey point of view, as the route had already been covered by Lieutenant Huddleston in the neighbourhood of Dirang Dzong, and from thence to Towang, by Captains Bailey and Morshead.

PREVIOUS KNOWLEDGE OF THE COUNTRY.

The previous knowledge of the country under report was nearly all contained in the maps.

North-east Frontier Series No. 14 N. W.
Scale 1 inch = 4 miles.
correction and addition 1908.

North-east Frontier Series No. 7.
Scale 1 inch = 8 miles.
corrected June 1908.

These maps were compiled from results obtained during the Akā Expedition of 1883-84.

(Survey Officer, Colonel Woodthorpe).

Daflā Expedition of 1874-75.

(Survey Officer, Captain Godwin Austen).

To the west of the area covered by this old map the *Explorer Nain Singh* had returned to India by the Towang Dirang Dzong and the Udalguri trade route in 1874-75, of this a rough traverse sketch and a good report was available.

On the far west, on the line Towang-Tashigong-Dewāngiri in Bhutān, there existed several rough routes by old explorers.

On the east there was the Mīri Mission Map of 1911-12.

In addition, there was the survey carried along the Bhutān-Darrang Boundary by Colonel Macdonald in 1872-73, of which maps are available.

As regards *triangulation* :—

(*a*) There were the Assam longitude and Assam Valley secondary G. T. series along the Brahmaputra Valley.

(*b*) A short series by Colonel Woodthorpe, which, however, was not sufficiently good to be used.

(*c*) A series further east by Captain Godwin Austen.

(*d*) Some points by Wahid Ali, observed from the G. T. series in Assam.

EXTENT OF WORK DONE.

(a) *Triangulation.*

Of Captain Godwin Austen's Daflā triangulation 1874-75 there is a printed chart available, but none such of Colonel Woodthorp's opposite Tezpur, and it was found, on going into the original computations, that the series was not sufficiently accurate for further extension.

In consequence a fresh start was made from the Assam Valley secondary G. T. Station of Pora Parbat and Sildubi, and also of the Forest triangulation of Singri (New) h. s.

(*b*) *Plane-table Survey* on scale 1 inch=4 miles.

Revision survey.	New rigorous survey.	New reconnaissance survey.
640	1,760	1,640

Total 4,040 square miles.

Of this area—

	Square miles.	Working days.
Lieutenant Huddleston surveyed ...	2,390	58
Surveyor Bhamba Ram	1,650	32
TOTAL ...	4,040	90

Amar Singh of No. 12 Party in Tezpur, took Bhamba Ram's place (when sick) for a month, and surveyed 650 square miles in 20 odd working days over the same area as Bhamba Ram's who was subsequently able to complete that area also.

The Revision Survey is contoured survey over that of Colonel Woodthorpe's work during the Akā Expedition, 1883-84, which proved accurate.

The New Rigorous Survey is contoured at an interval of 250 feet, and covers most of the inhabited area of the map.

The New Reconnaissance Survey is mostly hill-shaded work (with heights) of the uninhabited portions, and also includes work of small areas on one ray, of which the general lie can be taken as correct, though no attempt has been made to delineate detail.

NATURE OF THE COUNTRY AND WEATHER.

The country under report divides itself into two halves by a line drawn roughly through point 12,060 (square E—4), along spur down to Sepung, across Bichom River to Muraka, south westwards to Senchong and then continuing along the outer range of hills above the plains.

To the west of this line the river beds are much higher and flatter, the villages being situated from 5,000—7,000 above sea level. Except on the steep northern slopes, the country is open, covered with small oak and pine jungle, the undergrowth being burnt yearly for grazing. As described by Nāin Singh, magnificent Hemlock Spruces are found on the hills above 8,000—9,000, generally on the north side.

To the east of the above line the country suddenly changes to the usual Assam jungle and densely wooded hills found on the North East Frontier, the rivers run much lower and the villages are high up on the spurs above.

WEATHER.

The season was undoubtedly a good one, but, at the same time, the amount of rainfall in this more open country and the neighbouring Akā hills is evidently much less than that in the Daflā and Abor Hills further east.

CONCLUSION.

The only orders given to the Survey Officer were to accompany Captain Nevill on his tour, and take any opportunities given him and the surveyor to survey in new country.

The success of the operations is partly due to the better weather than usually obtained, easier country and, on the west, less necessity for escorts; but chiefly to Captain Nevill and the other officers of the Promenade who all most generously co-operated in their efforts to give the Survey Detachment every opportunity of doing useful work.

NOTE IN VINDICATION OF KINTHUP.

BY CAPTAIN G. F. T. OAKES, R.E.

For many years the explorations of Kinthup, more particularly his report of the existence of large falls on the Tsan-po in Eastern Tibet, have been the cause of considerable interest and have been received with scepticism by many owing to the romantic nature of his experiences.

Interest in the matter has been revived by the recent explorations on the N. E. Frontier. Though the Survey of India authorities of that time had "no doubt that his account was a *bonâ fide* story of his travels" and two other reliable Indian explorers both "placed complete reliance in Kinthup's statements," prominence has of late been given to the opinion of certain amateur geographers that the geographical information supplied by him was unreliable and merely collected in Tibet, the remainder of his narrative being fiction. It would therefore appear of much interest to make a brief examination of his work in the light of the recent explorations carried out by Captains Bailey and Morshead in 1913, and by the Abor Exploration Party in 1911-12-13.

Translation.

While proceeding with this examination it must be borne in mind that Kinthup delivered his narrative to Lama Ugyen Gyatsho (later Rai Bahadur) who is responsible for the translation: also that though familiar with the language of the people of Pemakö, he probably knew very little or nothing of the Abor language. In the Abor villages visited by him, judging from existing conditions, the Pemakö language (a dialect of Tibetan) would only have been known by a few of the men. This fact would account for the inferiority of the transliteration of his Abor names compared with those of Pemakö.

The nature of his work.

Until 1912 Kinthup was the sole authority for our geographical knowledge of the country bordering the Tsan-po from the neighbourhood of Gyāla down to Damro (or Padam), with the exception of Lama Serap Gyatsho who supplied a certain amount of information concerning the sacred places and administration of Pome. No one but he had succeeded in penetrating the hill country occupied by the savage tribes, known to us as Abors, with the exception of the military expedition of 1894 against the Padam Abors, which succeeded in penetrating to within sight of Damro and one or two expeditions which reached the neighbourhood of Kebang and Komsing, the last being that on which Mr. Williamson and Dr. Gregorson were murdered. After many months' daily experience of the Abors, of their distrust and hate of foreigners and their treacherous nature, one can only consider Kinthup fortunate to have returned alive.

Most of the country traversed by him, and not previously traversed by trained and reliable explorers has now been either surveyed in detail by the Abor Exploration Party or traversed by Captain Morshead, R.E., of the Survey of India. Kinthup's work has proved distinctly satisfactory, in fact, considering that he carried the whole in his memory until his return more than 4 years after his departure, it is remarkable. It must be remembered he was not a trained explorer.

All his names east of Tsetang, nearly 150 in number, have now been identified, with the exception of about 20 which include many caves and camps and also villages probably since abandoned. The descriptions of parts of his route are often most accurate and sometimes could not have been given more accurately in as few words. In the neighbourhood of Puparong "Kinthup noted that here the Tsan-po flows south." It was interesting to find that not only was this so, but that it did not flow due south again until in the neighbourhood of Komkar and Geku some 18 marches further south, a part not visited by him, thus indicating the care with which he endeavoured to determine the course of the river.

On the other hand for a few stages southward from Tongkyuk Dzong where he escaped from slavery, his route report was not good. Captain Morshead writes—" At this stage, Kinthup's first care was evidently to make good his escape from captivity, and certain portions of the road appear to have escaped his memory."

The Tsan-po Falls.

With regard to the Falls of the Tsan-po I cannot do better than quote Captain Morshead. He writes—" Referring, however, to Pemaköchung, he (Kinthup) makes the following erroneous statement: 'The Tsan-po is two chains distant from the monastery and about two miles off it falls over a cliff called Sinji-Chogyal from a height of about 150 feet. There is a big lake at the foot of the falls where rainbows are always observable.' Actually, the falls near Pemaköchung, to which the Tibetans have not given a name, are only some 30 feet in height, though it is true that a rainbow is visible on sunny days in the spray which is thrown up in immense clouds. On the other hand, falls called Sinji-Chogyal (Shingche Chögye) of approximately 150 feet do actually exist on the small side stream which, rising below the Tra La, joins the Tsan-po opposite Gyāla. It would seem that in the course of dictation and translation of Kinthup's narrative, the accounts of the two separate falls have been confused."

Subsequent to their return Captain Bailey has interviewed Kinthup, who said he remembered the place and thought that the fall (by comparing it to a house they were in) was about 50 feet high. This lends further support to the opinion that the error occurred in the dictation and translation.

Mr. Bentinck, Political Officer with the Abor Expedition in 1911-12, stated in his lecture before the Royal Geographical Society * with reference to Kinthup, " The first identifiable Abor village reached by him is Angging;

*See *Geographical Journal*, Volume XLI, No. 2, February 1913, page 106.

going southwards he gets four village names correct out of eleven, two of them being misplaced and the others more or less correct." This gives an entirely false idea of the work of the explorer as will be seen from the following table which shows all the Abor villages from Angi(ng) to Damro as now surveyed and as given by Kinthup.

Surveyed 1911-12.	Kinthup 1883-84.
Angi(ng)	Angi.
Singging	Shinging.
Paling	Hanging.
	Shobang.
Rikor	Puging.
Puging	Rikar.
Gette	Keti.
Simong	Shimong.
Mobuk or Gobuk	Mobuk.
Dalbuing	Tarpin.
Olon or Milang	Onlow or Onlet.
Damro or Padam	Miri Padam.

His Travels in the Abor Country.

Kinthup states that he reached Onlow or Onlet (now transliterated Olon), but not being allowed to proceed further towards the plains of India had to retrace his steps. Enquiry was made about him by Mr. W. C. M. Dundas, C.I.E., the Political Officer, and myself when at Olon (or Milang) in February 1913. Gams Tadang and Yubang gave the following information. When they were small children (*i.e.*, some 30 years ago) a Mönba (man from Pemakö) came down through Simong, Gobuk and Dalbuing (Kinthup's Tarpin) to Olon. They did not see him, but had heard of it and remembered it because Mönbas are never allowed to come past Dalbuing (a village under Simong) and seldom come past Simong. Further this man was prevented from proceeding to Damro, and returned *viâ* Simong.

In the Abor country he only appears to have made two geographical mistakes worth consideration, *viz.* :—

(*i*) Between Mobuk (or Gobuk) and Olon he mistook the Yamne valley for that of the Dihāng or Tsan-po.

(*ii*) He stated that "the river issuing from Sangacho Dzong joins the Tsan-po about 3 miles from Miri Padam."

As regards the first anyone who has experienced days of continuous mist and rain among the often very deceptive hill features in the Abor country, will realize how easy it is even for trained topographers to make such mistakes. As regards the second it is evident he was relying on hearsay or piecing information together wrongly, as he did not visit that part. He was also probably labouring under difficulty in not understanding the language of his informants.

Another error of his was in naming Damro, Miri Padam. The place is called Padam as often as Damro, and no doubt they told him that the next stage on the way to the plains after Padam was a Midhi (*i.e.*, Mishmi) village, because the trade route on leaving Damro first crosses the Baisha Pass and then continues through Mishmi villages to Sadiyā. Relating his story some months after and not having even visited Damro, he was quite liable to mix up the names Midhi (or Miri) and Padam.

The position of Damro as given by Kinthup's rough sketch carried down from Tibet and as given by the Political Officer at Sadiyā at that time from local information disagreed considerably. Again later another position for it was obtained from rough route sketches made on the Abor Expedition of 1894, when the village was sighted but not reached. It now proves that Kinthup's position was 19 miles S. W. of the true position ; Mr. Needham's position 53 miles N. N. E., and the 1894 Expedition's position 14 miles N. This comparison is remarkable, when it is considered that Kinthup's work was carried down over 200 miles from Tibet, while the 1894 Expedition only pene-

trated into the hills some 25 miles from the plains. Mr. Needham obtained his information from Padam Abors at Sadiyā.

Exception seems to have been taken to his report that he saw cows, pines, mangoes, and apples in the Abor country, but these are all to be seen at the present day, provided he meant coniferous trees and not necessarily pines. Surprise was caused by his omitting the somewhat important Abor village of Jido. It was found though, that this was built some years after his return to India. The opinion held by some, that he went up a high hill in Tibet, was pointed out the villages down the Tsan-po with their names, and then remembered them with all the details of the route, is ludicrous to say the least. An illustration of the unreliability of this type of information is the fact, that in the former season (1911-12) information had been obtained at Singging by Mr. Bentinck's party that Jido was six marches further up the river. It eventually proved to be only two.

Conclusion.

Kinthup started on his journey as assistant to a Chinese *lama*, who sold him as a slave and decamped to his own country. After the explorer had absconded and he had with difficulty escaped from slavery, that he should have continued the exploration shows the greatest pluck and perseverance and very rightly have his experiences been described as "a romance of the Survey of India." Since he is at present in poor circumstances earning a livelihood as a tailor, it is gratifying to know that steps are being taken to obtain him sufficient monetary reward to enable him to end his days in some slight degree of comfort.

A NOTE ON SCALES AND COST RATES OF CITY AND TOWN PLANS.*

BY MAJOR H. L. CROSTHWAIT, R.E.

1. The following notes have been prepared with a view to acting as a guide should a party be formed by the Survey of India for the purpose of taking up large-scale City and Town Surveys as part of the work of the department.

2. The department has had considerable experience of Cantonment Surveys, but they are executed on a scale of 16 inches to 1 mile, or 1-3960, as laid down in Military Works Services Circular No. 5-C, dated the 8th November 1913. This scale is much smaller than that usually required for Town Surveys which, generally speaking, varies from 100 feet to 41·66 feet (1-500) to 1 inch†. Uncongested areas are usually on the former and congested areas on the latter scale. Much, however, depends on the objects for which the survey is intended as well as on the congestion of buildings, and it is necessary to know these before any final decision can be come to. Each class of survey is, of course, based on traverses which become more elaborate as the scale increases.

3. *Scales.*—In England the scales adopted are, 1-2500 (1 inch = 208·3 feet) [and recently for Land Valuation purposes direct photographic enlargements of these maps to double scale, 1-1250] 1-1056 (1 inch = 88 feet), 1-528 (1 inch = 44 feet), and 1-500 (1 inch = 41·66 feet). Except for small and unimportant towns the 1-2500 scale has been found too small; the scale most favoured in the larger towns and cities being 1-500. But even this scale has been found too small in the case of very valuable London properties where the London County Council have made their own plans on a scale of 20 feet to 1 inch for Engineering works.

Madras has adopted three scales. (1) 1-396 or 1 inch = 33 feet for congested areas, (2) 1-792 or 1 inch = 66 feet for uncongested areas and (3) 1-1584 or 1 inch = 132 feet, for the more open areas on the outskirts of the city.

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* A note on the subject of Town Surveys is also to be found in Extract of Narrative Reports, Survey of India. 1903-04, by Captain Coldstream and Mr. R. B. Smart; also "Practice of Town Surveys in the United Kingdom" by Major C. L. Robertson, C.M.G., R.E.—Departmental Paper No. 4.

† Portions of Madras have been surveyed on a scale of 1 inch = 33 feet or 1-396, but this is exceptional.

4. *Suggested scales.*—It would, no doubt, be convenient from a survey point of view to introduce uniform scales for town surveys. I suggest the following:—

(*a*) 1-2500 for smaller unimportant places and for outskirts of large towns.

(*b*) 1-1000 and 1-500 for important towns and cities for uncongested and congested areas, respectively.

As to the actual scales to be adopted in any particular case, and the areas to which they are to apply, this would be a matter of arrangement, after personal consultation between the Officer in Charge of the survey and the Municipal authorities.

5. *Cost rates.*—To the Madras Presidency, where the surveys are carried out by the Local Government, we must look for the largest experience in this kind of work. Besides Madras city they have surveyed 29 other towns in the Presidency. Taking congested with the uncongested areas the cost rate in the Madras city works out to Rs. 7·2 per acre and for other towns Rs. 5·2 per acre. The survey of Delhi cost Rs. 6·3 per acre which compares fairly with Madras, the scale being 1 inch = 50 feet. On the other hand the survey of Calcutta works out to something like Rs. 18 for an average rate per acre.

Allahābād, all congested, cost Rs. 33 per acre. Mr. A. J. Wilson estimates the cost of an average city to work out at Rs. 16 per acre. I give these figures to show how the cost rate may vary according to different conditions. What are classed as uncongested areas in Calcutta may be relatively congested when considering other towns. If in the survey the gardens, and open areas found round many towns, are included the cost rate goes down, although portions of the city may be very congested. I should, therefore, be disinclined to give an estimate for any particular town before it had been inspected and the state of congestion ascertained, and the purpose for which the survey is required gone into.

6. Attached is a table showing the result of information collected, so far, from answers to enquiries.

7. Following this is given an abstract of the cost of the Hyderābād Municipal Survey kindly supplied by Mr. L. Munn, Superintendent of the Hyderābād Survey.

Cost of Town Survey.

Locality.	Scale.	Cost rate per acre.	REMARKS.
Calcutta	1 inch = 50 feet 1 inch = 100 feet	Rs. 23, congested „ 17, uncongested. „ 13, not stated whether congested or uncongested. Includes field work, mapping and publication.	See Mr. R. B. Smart's letter, dated 16th September 1914.
Delhi	1 inch = 50 feet	Rs. 6·3, not stated whether congested or not. Probably includes gardens round city.	See Secretary, Delhi Municipality No. $\frac{2754}{T}$, dated 22nd September 1914.
Lahore	$\frac{1}{500}$ or 1 inch = 41·66 feet.	Rs. 32, no particulars given. Includes cost of mapping and printing.	See Deputy Commissioner, Delhi, No. 2844, dated 26th October 1914.
Bombay	1 inch = 40 feet	Rs. 18·1, includes only field work and supervision by inspectors, but not European supervision.	See Mr. W. Newland's No. 687, dated 7th October 1914.
29 towns in Madras Presidency.	1 inch = 40 feet to 1 inch = 160 feet.	Average Rs. 5·2, details regarding congestion are not given.	

Cost of Town Survey—contd.

Locality.	Scale.	Cost rate per acre.	Remarks.
Cantonment Surveys.			
Delhi . . .	4 inches=1 mile	Rs. 0·50 Re-survey.	Taken from General Report, 1912-13, page 18.
Quetta and Saugor .	16 „ =1 „	„ 2·75 „	
Saugor . . .	64 „ =1 „	„ 6·37 „	

Abstract of Cost of the Hyderabad Municipal Survey.

BY MR. L. MUNN.

SCALE 1 INCH TO 50 FEET. (ALL COSTS IN O. S. RUPEES).

No.	Class of work.	Total work in acres.	Total cost.	Cost per acre.	Remarks.
			Rs. a. p.	*Rs. a. p.*	
1	Traverse . .	21,760	26,109 6 8	1 3 3	
2	Computation .	21,760	8,477 1 4	0 6 3	
3	Plotting . .	21,760	6,104 4 7	0 4 6	
4	Plane-table .	21,760	80,302 4 9	3 11 0	
5	Mapping . .	18,624	23,113 10 9	1 3 10	
6	Levelling .	9,952	7,073 15 10	0 11 4	
	TOTAL WORK .	...	1,51,180 11 11	7 8 2	
7	Reproduction .	4,972	17,054 3 0	3 6 10	
8	Reduction .	6,771	5,421 1 0	0 12 9	

NOTE :—

In calculating the cost rates of the above heads, no remuneration to be granted to the superintendent, is included.

BOMBAY CITY SURVEY.

COMPLETION OF THE MAIN FRAMEWORK.

BY MAJOR E. A. TANDY, R.E.

Outturn.—Field work commenced on 17th November, and closed, on completion of the whole work, on 15th February. The outturn consisted in fixing the remaining 5 triangulation stations, and in measuring 32 miles of traverse, which involved 307 theodolite stations, of which 32 were permanently marked. With the two observers at work, an outturn of nearly a mile of traverse work a day was found possible where the roads were open and free from traffic; but the average, including congested areas, was under half a mile per working day.

Methods.—Twenty readings were taken for each horizontal angle with an 8-inch micrometer theodolite, and linear measurements were made by very carefully aligned steel tapes, laid along the ground under a uniform strain of

20 pounds. Daily comparisons of tapes with a standard were made, and also during work the temperature of each third tape was recorded at the time of measurement. Corrections for daily variations in length, and for temperature, were thus applied to each measurement. Vertical angles were taken between station and station, but intermediate variations of slope were only observed when very marked.

As far as possible stations were made equidistant, so as to obviate the delay (and possible slight inaccuracy) entailed in refocussing the theodolite between back and forward observations.

Defects.—The suitability of the framework for its purpose of controlling the detail survey has now been to some extent tested in practice and it may be of use to record such defects as have come to light.

(*i*) The number of permanently marked stations might with advantage have been increased.

(*ii*) The omission to provide permanent azimuth points visible from each station was a serious defect, as without such points the detail traversers had much difficulty in checking their angular measures.

(*iii*) The precaution of taking a duplicate linear measurement of less accuracy, as an immediate check on blunders, was omitted.

(*iv*) The adjusting discs, by which the exact spot for the end of each tape was marked, gave trouble, owing to the wooden slides warping and jamming. A heavier disc with metal bearings and tangent screw is desirable. Otherwise the special devices adopted for this work proved most satisfactory.

Distribution of traverse errors.—Closing errors were very carefully distributed by Major Tandy's method, in the application of which fresh experience has been gained. It has been found that results can be most quickly obtained by a combination of this method (as described in The Handbook of Topography, Chapter IV) with the old Revenue method. If the residuals got from the first closing, as entered on the diagram in Tandy's method, are totalled up clockwise (changing sign where necessary) for each closed circuit, the result is *the same* as that got by closing the circuit on itself in the Revenue method, and can similarly be written in the centre of the block. These totals are useful in quickly locating the chief sources of error; after which Tandy's method facilitates the attainment of the best solution possible, having a marked advantage in the proportionate distribution of errors over long lines in a network.

The greater part of the previous season's results were also re-opened, and treated in the same way, so that the few cases of excessive error which they bore were shown to be due to unfortunate closing, and readily disappeared under the diagrammatic method of distribution.

Accuracy of traverse.—The assessment of the real accuracy of a traverse framework is a complicated matter. The discrepancies arising from the preliminary closing are altogether fortuitous, and even the result of taking their mean does not necessarily give a correct idea of the character of the work, and affords no clue as to which are really the weaker parts, or their reliability. To get this we must first distribute the fortuitous closing errors as uniformly as possible over the framework, so as to obtain the most probable position for each point.

Since the position so assigned to each point depends on the evidence of two or more lines which close on it, and also is in each case the result of *eliminating* the closing errors, the assigned position will probably be far more correct than the closing error of any one line would indicate. We may therefore safely say that when all closing errors have been as uniformly dispersed as possible, the average error of position of the points will be much less than the mean of the closing errors, and we may guarantee that the position of even the most doubtful point is correct well within the limits of the largest of our final closing errors.

On this basis we may say that great majority of the points fixed for the main framework of Bombay contain linear errors of mutual position well within the limit of 1 in 10,000, and that if there are any errors exceeding this

limit they will only do so by a very small amount.

The actual facts are as follows:—

The first thing noted was that the chaining, after dispersal of errors, was persistently longer than the triangulated distances, and had to be reduced in closing, by an amount averaging about 1 in 4,000. Part of this error might be attributed to unobserved fluctuations in slope, but it was quite clear that in the flat parts of Bombay these could not be sufficient to account for this discrepancy, which was far larger than should be expected from such work. Finally the certified invar standard tape itself was tested, and was found too short by about 1 in 5,500. This surprising defect in the standard explains the whole difficulty, since the very slight residual excess in chained distances, beyond this 1 in 5,500, might quite well be due to insufficient correction for fluctuations in slope.

In order therefore to deduce their real values, we have to apply to the closing errors this correction for error of standard, by subtracting 1 in 5,500 from each of them. Also all discrepancies between triangulation and traversing of less than 1 in 50,000 have been treated as 0, being beyond the reliability of the triangulation and all possible requirements.

Thus treated we find the average amount (without regard to sign) of the closing errors, for the last season's work in the flat parts of Bombay, to be 1 in 12,000. The largest closing error is 1 in 6,000, and the errors show a tendency to excess on the part of the traverse work which may be fairly assigned to unobserved fluctuations of slope.

This latter assumption is confirmed by the fact that on Malabar Hill, where the work was just as careful but the slopes were more fluctuating, we find the traverse excess more marked, averaging 1 in 7,600, and rising in 3 cases (where the line was most bumpy) to about 1 in 4,000. Since these larger discrepancies are thus found to have a real cause, it is clear that they are not matters of doubt in the accuracy of our final determinations; for the final determination itself effects the required reduction in the traversed distances, and thus eliminates the excesses due to unobserved fluctuations of slope.

Summary.—We may therefore say that the determinations of distances in the main framework (wherever the principle of dispersal has been fully carried out) can hardly contain any error amounting to 1 in 10,000, and will generally be much better than this.

Since the expansions and contractions of map paper are liable to exceed 1 in 1,000, and very few practical field measurements attain even this accuracy, it will be clear that the methods adopted have given to Bombay City a main traverse framework whose accuracy should amply meet all possible requirements.

The permanent value of the framework to the City will depend on the success attained by the local authorities in the preservation of the marks. If they are lost the framework ceases to exist and its value for purposes of future reference is thrown away.

Appendix.

LIST OF PUBLICATIONS

OF THE

SURVEY OF INDIA

CONTENTS.

A—HISTORY AND GENERAL REPORTS.

B—GEODETIC WORKS OF REFERENCE.

C—CATALOGUES AND INSTRUCTIONS.

D—MISCELLANEOUS PAPERS.

APPENDIX

List of Survey of India Publications.

A—HISTORY AND GENERAL REPORTS
B—GEODETIC WORKS OF REFERENCE
C—CATALOGUES AND INSTRUCTIONS
D—MISCELLANEOUS PAPERS

Note.—Unless otherwise stated, the publications are obtainable from The Superintendent, Map Publication, 13, Wood Street, Calcutta.

A—HISTORY AND GENERAL REPORTS.

MEMOIRS.

1. A Memoir on the Indian Surveys. *By C. R. Markham* . *India Office*, London, 1871.
2. Ditto (second edition). *By C. R. Markham, C.B., F.R.S.* . . . . . . *India Office*, London, 1878.
3. Abstract of the Reports of the Surveys and of other Geographical Operations in India, 1869—78. *By C.R. Markham and C. E. D. Black* . . . . *India Office*, London. Published annually between 1871 and 1879.
4. A Memoir on the Indian Surveys, 1875—1890. *By C. E. D. Black* . . . . *India Office*, London 1891.

ANNUAL REPORTS.

Reports of the **Revenue Branch** . . 1851 to 1877.—(1857—1870 out of print).
Ditto **Topographical Branch** . 1861 to 1877.—(1862—1866 and 1872—1875 out of print).
Ditto **Trigonometrical Branch**. 1861 to 1878.—(1863—1867 and 1868-1869 out of print).

In 1878 the three branches were amalgamated, and from that date onwards annual reports in single volumes for the whole department, are available as follows :—

General Reports { from 1877—1900 *at Rs. 3/- per volume.*
from 1900—1914 *at Rs. 2/- per volume.*

From 1900 onwards the Report has been issued annually in the form of a condensed statement known as the "**General Report**," supplemented by fuller reports, which were called "**Extracts from Narrative Reports**" up to 1909, and since then have been styled "**Records of the Survey of India.**" These fuller reports are available as follows :—

(*a*) "**Extracts**" **Volumes** *at Rs. 1/8 per volume.*

1900-01.—Recent Improvements in Photo-Zincography. G. T. Triangulation, Upper Burma. Latitude Operations. Experimental Base Measurement with Jäderin Apparatus. Magnetic Survey. Tidal and Levelling. Topography in Upper Burma. Calcutta, 1903. (Out of print).

1901-02.—G. T. Triangulation, Upper Burma. Latitude Operations. Magnetic Survey. Tidal and Levelling. Topography in Upper Burma. Topography in Sind. Topography in the Punjab. Calcutta, 1904.

1902-03.—Principal Triangulation, Upper Burma. Topography, Upper Burma. Topography, Shan States. Survey of the Sāmbhar Lake. Latitude Operations. Tidal and Levelling. Magnetic Survey. Introduction of the Contract System of Payment in Traverse Surveys. Traversing with the Subtense Bar. Compilation and Reproduction of Thāna Maps. Calcutta, 1905.

1903-04.—Magnetic Survey. Pendulum. Tidal and Levelling. Astronomical Azimuths. Utilization of old Traverse Data for Modern Surveys in the United Provinces. Identification of Snow Peaks in Nepāl. Topographical Surveys in Sind. Notes on Town and Municipal Surveys. Notes on Riverain Surveys, Punjab. Calcutta, 1906.

1904-05.—Magnetic Survey. Pendulum Operations. Tidal and Levelling. Triangulation in Baluchistan. Survey Operations with the Somaliland Field Force. Calcutta, 1907.

1905-06.—Magnetic Survey. Pendulum Operations. Tidal and Levelling. Topography, Shan States. Calcutta, 1908.

1906-07.—Magnetic Survey. Pendulum Operations. Tidal and Levelling. Triangulation in Baluchistan. Astronomical Latitudes. Topography in Shan States. Calcutta, 1909.

1907-08.—Magnetic Survey. Tidal and Levelling. Astronomical Latitudes. Pendulum Operations. Topography, Shan States. Calcutta, 1910.

1908-09.—Magnetic Survey. Tidal and Levelling. Pendulum Operations. Triangulation. Calcutta, 1911.

ANNUAL REPORTS—(*continued*).

(*b*) **"Records of the Survey of India"** *at Rs. 4/- per volume.*

Vol. I.—1909-10.—Annual Reports of parties and offices. . . . . Calcutta, 1912.
II.—1910-11.—Annual Reports of parties and offices. . . . . Calcutta, 1912.
III.—1911-12.—Annual Reports of parties and offices. . . . . Calcutta, 1913.
IV.—1911-13.—*Explorations on the North-East Frontier.* . . . . Calcutta, 1914.
V.—1912-13.—Annual Reports of parties and offices. . . . . Calcutta, 1914.
VI.—1912-13.—*Link connecting the Triangulations of India and Russia.* . . . . Dehra Dūn, 1914.
VII.—1913-14.—Annual Reports of parties and offices. . . . . Calcutta, 1915.
VIII. { **1865-79.—Part I,** / **1879-92.—Part II,** } *Explorations in Tibet and neighbouring regions (at press)* . Dehra Dūn, 1915.

SPECIAL REPORTS.

1. *Report on the Mussoorie and Landour, Kumaun and Garhwal, Ranikhet and Kosi Valley Surveys extended to Peshawar and Khagan Triangulation during 1869-70, *by Major T. G. Montgomerie, R.E.* (Out of print.)

2. *Account of the Survey Operations in connection with the Mission to Yarkand and Kashghar in 1873-74. *By Captain Henry Trotter, R.E.* Calcutta, 1875.

3. Report on the Trans-Himalayan Explorations during 1869. (Out of print.)

4. Report on the Trans-Himalayan Explorations during 1870. Dehra Dūn, 1871. *Price Re. 1.*

5. Report on the Trans-Himalayan Explorations during 1878. Calcutta, 1880. (Out of print.)

"Notes of the Survey of India" are issued monthly.

B—GEODETIC WORKS OF REFERENCE.

(*Obtainable from the Superintendent of the Trigonometrical Survey, Dehra Dūn, U. P.*).

EVEREST'S GREAT ARC BOOKS.

1. An account of the Measurement of an Arc of the Meridian between the parallels of 18° 3′ and 24° 7′. *East India Company.* . . . . *London,* 1830. (Out of print.)

2. An account of the Measurement of two Sections of the Meridional Arc of India, bounded by the parallels of 18° 3′ 15″—24° 7′ 11″—and 29° 30′ 48″. *East India Company.* . . . . London, 1847. (Out of print.)

3. Engravings to illustrate the above. London, 1847. (Out of print.)

G.T.S. VOLUMES—Describing the Operations of the Great Trigonometrical Survey. *Price Rs. 10-8 per volume, except where otherwise stated.*

Vol. I.—Standards of Measure and Base-Lines, also an Introductory Account of the early Operations of the Survey, during the period of 1800-1830. . . . . Dehra Dūn, 1870. (Out of print.)

II.—A History and General Description of the Reduction of the Principal Triangulation. Dehra Dūn, 1879. (Out of print.)

III.—North-West Quadrilateral.—The Principal Triangulation, the Base-Line Figures, the Karāchi Longitudinal, N. W. Himālaya, and the Great Indus Series. . . Dehra Dūn, 1873. (Out of print.)

IV.—North-West Quadrilateral.—The Principal Triangulation, the Great Arc—Section 24°—30°, Rahūn, Gurhāgarh and Jogi-Tila Meridional Series and the Sutlej Series. . Dehra Dūn, 1876.

IV A.—North-West Quadrilateral.—The Principal Triangulation, the Jodhpore and the Eastern Sind Meridional Series with the Details of their Reduction and the Final Results. . Dehra Dūn, 1886.

V.—Pendulum Operations of Captains J. P. Basevi and W. J. Heaviside, and their Reduction. Dehra Dūn and Calcutta, 1879.

VI.—South-East Quadrilateral.—The Principal Triangulation and Simultaneous Reduction of the following Series:—Great Arc—Section 18° to 24°, the East Coast, the Calcutta and the Bider Longitudinal, the Jabalpur and the Bilāspur Meridionals. . . Dehra Dūn, 1880. (Out of print.)

VII.—North-East Quadrilateral.—General Description and Simultaneous Reduction. Also Details of the following five Series:—North-East Longitudinal, the Budhon Meridional, the Rangīr Meridional, the Amua Meridional, and the Karāra Meridional . . . . Dehra Dūn, 1882.

VIII.—North-East Quadrilateral.—Details of the following eleven Series:—Gurwāni Meridional, Gora Meridional, Hurilāong Meridional, Chendwār Meridional, North Pārasnāth Meridional, North Malūncha Meridional, Calcutta Meridional, East Calcutta Longitudinal, Brahmapūtra Meridional, Eastern Frontier—Section 23° to 26°, and Assam Longitudinal. . . . . . . Dehra Dūn, 1882.

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* For Departmental use only.

G.T.S. VOLUMES—(*continued.*)

Vol. IX.—**Telegraphic Longitudes**—during the years 1875-77 and 1880-81. . . . Dehra Dūn, 1883.
X.—**Telegraphic Longitudes**—during the years 1881-82, 1882-83, and 1883-84. . Dehra Dūn, 1887.
XI.—**Astronomical Latitudes**—during the period 1805 to 1885. . . . . . Dehra Dūn, 1890.
XII.—**Southern Trigon**—General Description and Simultaneous Reduction. Also details of the following two Series :—Great Arc—Section 8° to 18°, and Bombay Longitudinal. . . Dehra Dūn, 1890.
XIII.—**Southern Trigon**—Details of the following five Series :—South Konkan Coast, Mangalore Meridional, Madras Meridional and Coast, South-East Coast, and Madras Longitudinal. . Dehra Dūn, 1890.
XIV.—**South-West Quadrilateral**—Details of Principal Triangulation and Simultaneous Reduction of its component Series. . . . . Dehra Dūn, 1890.
XV.—**Telegraphic Longitudes**—from 1885 to 1892 and the Revised Results of Volumes IX and X; also the Simultaneous Reduction and Final Results of the whole Operations. . Dehra Dūn, 1893.
XVI.—**Tidal Observations**—from 1873 to 1892, and the Methods of Reduction. . . Dehra Dūn, 1901.
XVII.—**Telegraphic Longitudes**—during the years 1894-95-96. The Indo-European Arcs from Karāchi to Greenwich. . . . . Dehra Dūn, 1901.
XVIII.—**Astronomical Latitudes**—(1885 to 1905) and the Deduced Values of Plumb-line Deflections. Dehra Dūn, 1906.
XIX.—**Levelling of Precision in India**—(1858 to 1909) . . . . . . Dehra Dūn, 1910.
XIXA.—**Bench-Marks** on the **Southern** Lines of Levelling. . . . Dehra Dūn, 1910. *Price Rs. 5.*
XIXB.—**Bench-Marks** on the **Northern** Lines of Levelling. . . . . Dehra Dūn, 1910. *Price Rs. 5.*

SYNOPTICAL VOLUMES—Giving charts, descriptions of stations, and full synopses of co-ordinates and heights of all stations and points fixed by Principal and Secondary **Triangulation.***

Price Rs. 2 per volume unless otherwise stated.

Italic figures are in chronological order and refer to the Index Chart of the G. T. Survey.

North-West Quadrilateral.

Vol. I.—The Great Indus Series (*32*). Dehra Dūn, 1874.
II.—The Great Arc—Section 24° to 30° (*6*). Dehra Dūn, 1874.
III.—The Karāchi Longitudinal Series (*25*). Dehra Dūn, 1874.
IV.—The Gurhāgarh Meridional Series (*23*). Dehra Dūn, 1875.
V.—The Rahūn Meridional Series (*33*). Dehra Dūn, 1875.
VI.—The Jogi-Tila Meridional Series (*37*) and the Sutlej Meridional Series (*45*). Dehra Dūn, 1875.
VII.—The N. W. Himālaya Series (*22*) and the Triangulation of Kashmīr (*36*). Dehra Dūn, 1879.
VIIA.—The Jodhpore Meridional Series (*62*) and the Eastern Sind Meridional Series (*64*). Dehra Dūn, 1887.

South-East Quadrilateral.

Vol. VIII.—The Great Arc—Section 18° to 24° (*8*). Dehra Dūn 1878.
IX.—The Jabalpur Meridional Series (*53*). Dehra Dūn, 1878.
X.—The Bider Longitudinal Series (*43*). Dehra Dūn, 1880.
XI.—The Bilāspur Meridional Series (*58*). Dehra Dūn, 1880.
XII.—The Calcutta Longitudinal Series (*5*). Dehra Dūn, 1880.
XIII.—The East Coast Series (*24*). Dehra Dūn, 1880.
XIIIA.—The South Pārasnāth (*1*) and the South Malūncha Meridional Series (*17*). Dehra Dūn, 1885.

North-East Quadrilateral.

Vol. XIV.—The Budhon Meridional Series (*2*). Dehra Dūn, 1883.
XV.—The Rangir Meridional Series (*4*). Dehra Dūn, 1883.
XVI.—The Amua Meridional Series (*3*) and the Karāra Meridional Series (*12*). Dehra Dūn, 1883.
XVII.—The Gurwani Meridional Series (*19*) and the Gora Meridional Series (*15*). Dehra Dūn, 1883.
XVIII.—The Hurilāong Meridional Series (*21*) and the Chendwār Meridional Series (*14*). Dehra Dūn, 1883.
XIX.—The North Pārasnāth (*27*) and the North Malūncha Meridional Series (*13*). Dehra Dūn, 1883.
XX.—The Calcutta Meridional (*16*) and the Brahmapūtra Meridional Series (*56*). Dehra Dūn, 1883.
XXI.—The East Calcutta Longitudinal (*48*) and the Eastern Frontier Series—(23° to 26°) (*44*). Dehra Dūn, 1883.
XXII.—The Assam Valley Triangulation, E. of Meridian 92° (*55*). Dehra Dūn, 1891. (Out of print.)
XXXV.—The North-East Longitudinal Series (*2*). Dehra Dūn, 1909. *Price Re. 1.*

Southern Trigon.

Vol. XXIII.—The South Konkan Coast Series (*11*). Dehra Dūn, 1891.
XXIV.—The Mangalore Meridional Series (*49*). Dehra Dūn, 1891.
XXV.—The South-East Coast Series (*63*). Dehra Dūn, 1891.
XXVI.—The Bombay Longitudinal Series (*7*). Dehra Dūn, 1892.
XXVII.—The Madras Longitudinal Series (*54*). Dehra Dūn, 1892.
XXVIII.—The Madras Meridional and Coast Series (*46*). Dehra Dūn, 1892.
XXIX.—The Great Arc Meridional Series—Section 8° to 18° (*9*). Dehra Dūn, 1899.

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* Special charts can be supplied of those series for which no Synoptical Volumes are available, *viz.* :—all Burma, Chittagong, and Baluchistan triangulation, the Assam Longitudinal, the Sambalpur Meridional, and the Gilgit Series, with a few recent Secondary Series in India.

South-West Quadrilateral.

Vol. XXX.—The Abu Meridional Series (*26*), and the Gujarāt Longitudinal Series (*29*). Dehra Dūn, 1892.
XXXI.—The Khānpisūra Meridional Series (*18*). Dehra Dūn, 1893.
XXXII.—The Singi Meridional Series (*10*). Dehra Dūn, 1893.
XXXIII.—The Cutch Coast Series (*35*). Dehra Dūn, 1893.
Addendum to the Cutch Coast Series, (*Indus delta*) (separate pamphlet). Dehra Dūn, 1902.
XXXIV.—The Kāthiawār Meridional Series (*28*). Dehra Dūn, 1894.

TRIANGULATION PAMPHLETS, with charts, are now being issued for every square degree, giving the results of all minor triangulation, as well as that shown in Synoptical Volumes—(*vide* Index No. 9 of Records Volume.)

LEVELLING PAMPHLETS—Giving heights and descriptions of all **Bench-marks,** fixed by levelling of Precision in India and Burma. Each pamphlet embraces an area of 4° × 4° and the numbering is the same as that of the corresponding sheets of the 1/M map of India. Each is illustrated by a map of the area. *Price Rupees 2 per pamphlet, except where otherwise stated.*

Pamphlet	No.	Latitude.	Longitude.	Published.	Pamphlet	No.	Latitude.	Longitude.	Published.
India	35	24°—28°	64°—68°	Dehra Dūn, 1911.	India	57	12°—16°	76°—80°	Dehra Dūn, 1912.
„	38	32°—36°	68°—72°	„ 1912.	„	58	8°—12°	76°—80°	„ 1913.
„	39	28°—32°	68°—72°	„ 1913.	„	63	24°—28°	80°—84°	„ 1911.
„	40	24°—28°	68°—72°	„ 1911.	„	64	20°—24°	80°—84°	„ 1912.
„	41	20°—24°	68°—72°	„ 1913.	„	65	16°—20°	80°—84°	„ 1913.
„	43	32°—36°	72°—76°	„ 1913.	„	66	12°—16°	80°—84°	„ 1912.
	„	Addendum		(*at press.*)	„	72	24°—28°	84°—88°	„ 1912.
„	44	28°—32°	72°—76°	„ 1912.	„	73	20°—24°	84°—88°	„ 1913.
„	45	24°—28°	72°—76°	„ 1911.	„	74	16°—20°	84°—88°	„ 1913.
„	46	20°—24°	72°—76°	„ 1912.	„	78	24°—28°	88°—92°	„ 1912.
„	47	16°—20°	72°—76°	„ 1912.	„	79	20°—24°	88°—92°	„ 1912.
„	48	12°—16°	72°—76°	„ 1912.	„	83	24°—28°	92°—96°	„ 1912.
„	49*	8°—12°	72°—76°	„ 1911.	Burma	84	20°—24°	92°—96°	„ 1911.
„	52*	32°—36°	76°—80°	„ 1912.		„	Addendum		„ 1914.
„	53	28°—32°	76°—80°	„ 1912.	„	85	16°—20°	92°—96°	„ 1913.
„	54	24°—28°	76°—80°	„ 1911.	„	92	24°—28°	96°—100°	„ 1911.
„	55	20°—24°	76°—80°	„ 1912.	„	93	20°—24°	96°—100°	„ 1911.
„	56	16°—20°	76°—80°	„ 1912.	„	94	16°—20°	96°—100°	„ 1911.

* Price Re. 1.

TIDE TABLES—

Since 1881 Tidal predictions based on the observations of the Survey of India have been published annually by the *India Office, London.* The tables give the time and height of high and low water for every day in the year at each port, and are published early in the previous year. Current tables are available for the following 40 ports :—

Western Ports—

Suez (Egypt)—Perim—Aden—Maskat—Bushire—Karachi—Okha Point and Bet Harbour (Gulf of Cutch)—Porbandar—Port Albert Victor (Kathiawar)—Bhavnagar—Bombay (Apollo Bandar)—Bombay (Prince's Dok)—Mormugao (Goa)—Karwar—Beypore (near Calicut)—Cochin—Minicoy (Indian Ocean)—Tuticorin—Pamban Pass (Island of Ramesvaram.)

Eastern Ports—

Galle (Ceylon)—Trincomalee (Ceylon)—Colombo (Ceylon)—Negapatam—Madras—Cocanada—Vizagapatam—False-Point—Dublat (Saugor Island)—Diamond Harbour—Kidderpore (Calcutta)—Chittagong—Akyab—Diamond Island (Burma)—Bassein—Elephant Point (Burma)—Rangoon—Amherst—Moulmein—Mergui—Port Blair.

The Tide Tables are issued in the following forms :—

(i) **Combined Volume**—including all the above ports—*Price Rs. 4.*
(ii) **Part I and Part II**—including Western and Eastern ports respectively—*Each part Rs. 2.*
(iii) **Pamphlets**—giving separately the tables for individual ports or for small local groups of ports—*Prices varying from As. 8 to Rs. 1-8 per pamphlet.*

C—CATALOGUES AND INSTRUCTIONS.

DEPARTMENTAL ORDERS.

From 1878 to 1885 the Surveyor General's orders were all issued as "*Circular Orders.*" Since then they have been classified as follows :—

From 1885 to 1904 as
1.—**Government of India Orders** (called "*Circular Orders*" up to 1898.)
2.—**Departmental Orders (Administrative).**
3.—**Departmental Orders (Professional).**

DEPARTMENTAL ORDERS—(*continued.*)

In 1904 the various orders issued since 1878 were reclassified as follows :—

1.—Government of India Orders.—*Number to date 654.*
2.—Circular Orders (Administrative).—*No. 335.*
3.—Circular Orders (Professional).—*No. 184.*
4.—Departmental Orders (appointments, promotions, transfers, etc.).

These are numbered serially and had reached the above numbers by March 1915. *Government of India Orders* and *Circular Orders* (*Administrative*) are bound up in volumes from time to time, as shown below, while *Circular Orders* (*Professional*) are gradually incorporated in the Survey Hand-books. Besides the above, temporary orders have been issued since 1910 in the form of "**Circular Memos**". These either lapse or become incorporated in some more permanent form, and are therefore only numbered serially for each year. Bound volumes of orders are available as follows :—

1. Government of India Orders (Departmental) 1878-1903.—Calcutta, 1904.
   Ditto (ditto) 1904-1908.—Calcutta, 1909.
   Ditto (ditto) 1909-1913.—Calcutta, 1915.
2. Circular Orders (Administrative) 1878-1903.—Calcutta, 1904.
   Ditto (ditto) 1904-1908.—Calcutta, 1909.
   Ditto (ditto) 1909-1913.—Calcutta, 1915.
3. Regulations on the subject of Language Examinations for Officers of the Survey of India. Calcutta, 1914.
4. Map publication Orders 1908-1914 (*Superintendent, Map Publication's Orders*).—Calcutta, 1914.
5. Specimens of papers set at Examinations for the Provincial Service.—Dehra Dūn, 1903.—*Gratis.*

CATALOGUES AND LISTS.

1. **Catalogue of Maps** published by the Survey of India. Second edition. Calcutta, 1915. *Price Re. 1.*
   NOTE.—Lists are issued quarterly of new maps published during each quarter, and similar lists for each month appear in the monthly NOTES OF THE SURVEY OF INDIA.
2. **Catalogue of Maps** of the Bombay Presidency, Calcutta, 1913. *Price As. 4.*
3. **List of Survey of India publications** (published annually)—*Gratis.*
4. **Price List of Mathematical Instrument Office.** Calcutta, 1913.
5. Catalogue of Books in the Headquarters Library, Calcutta, 1901. (Out of print.)
6. Catalogue of Scientific Books and Subjects in the Library of the G. T. Office. Dehra Dūn, 1908. *Price Re. 1.*
7. Catalogue of Books in the Library of the Trigonometrical Survey Office.* Dehra Dūn, 1911. *Price Re. 1.*
8. **Green Lists**—PART I.—List of Officers in the Survey (*half-yearly to dates 1st Jan. and 1st July*)—Calcutta.
   PART II.—History of Services of Officers of the Survey of India (*annually to date 1st July*)—Calcutta.
9. **Blue Lists**—Ministerial and Subordinate Establishments of the Survey of India.
   PART I.—Headquarters and Dehra Dūn Offices (*published annually to date 1st April*)—Calcutta.
   PART II.—Circles and parties (*published annually to date 1st January*)—Calcutta.

TABLES AND STAR CHARTS.

1. **Auxiliary Tables**—to facilitate the calculations of the Survey of India. Fourth Edition, revised. Dehra Dūn, 1906. *Price Rs. 4 in cloth and calf, or Rs. 2 in paper and boards.*
2. Tables for Graticules of Maps. Extracts for the use of **Explorers**. Dehra Dūn, 1910. *Price As. 4.*
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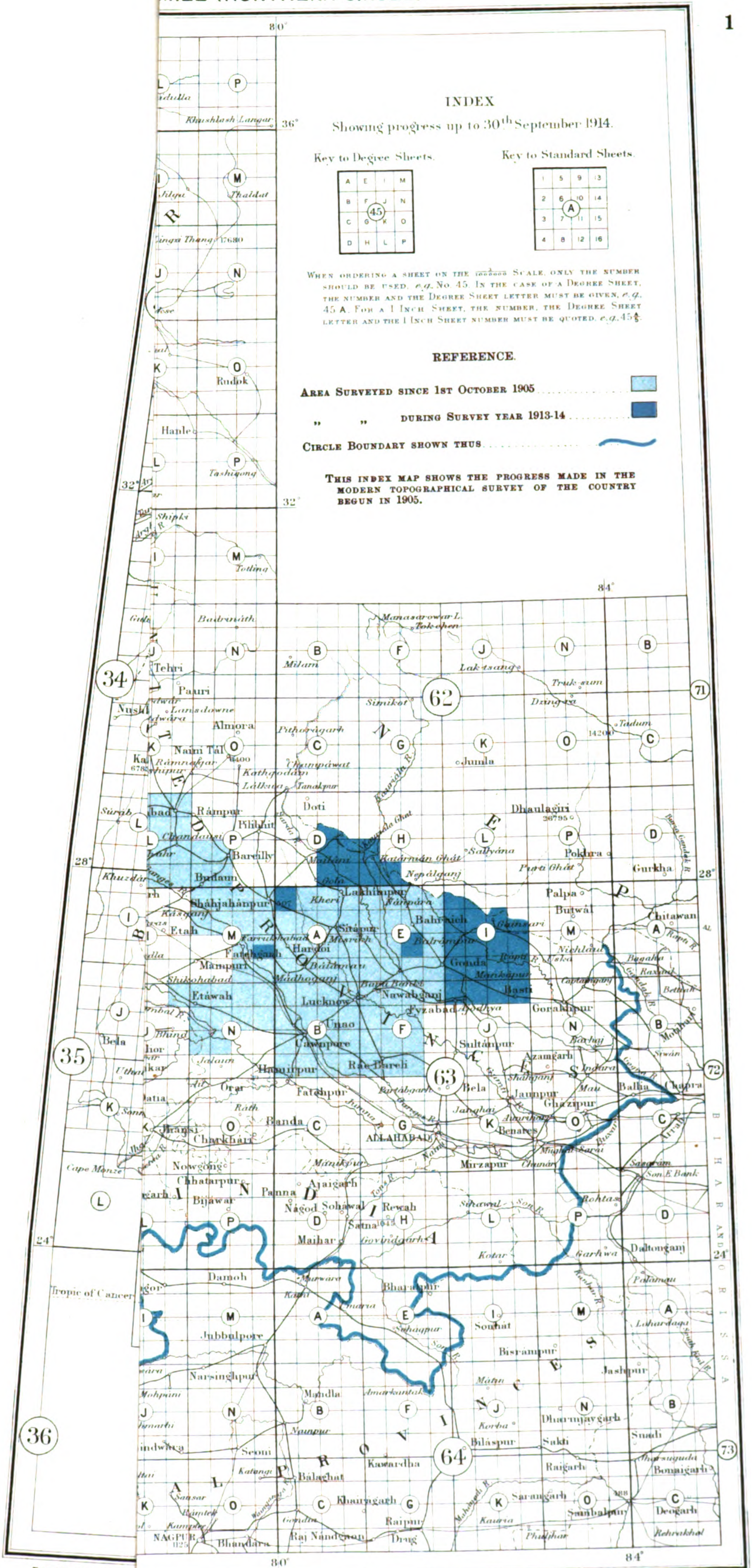

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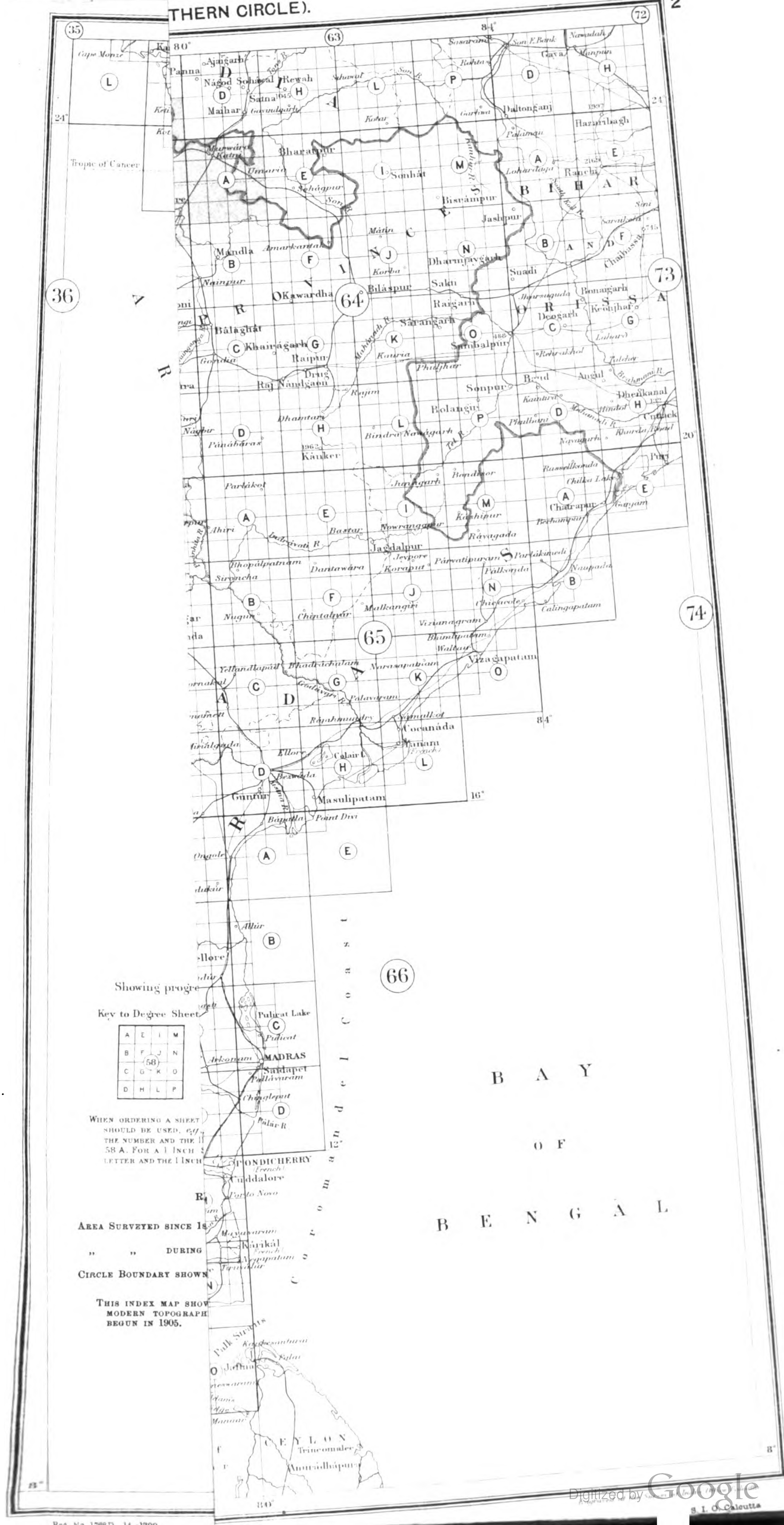

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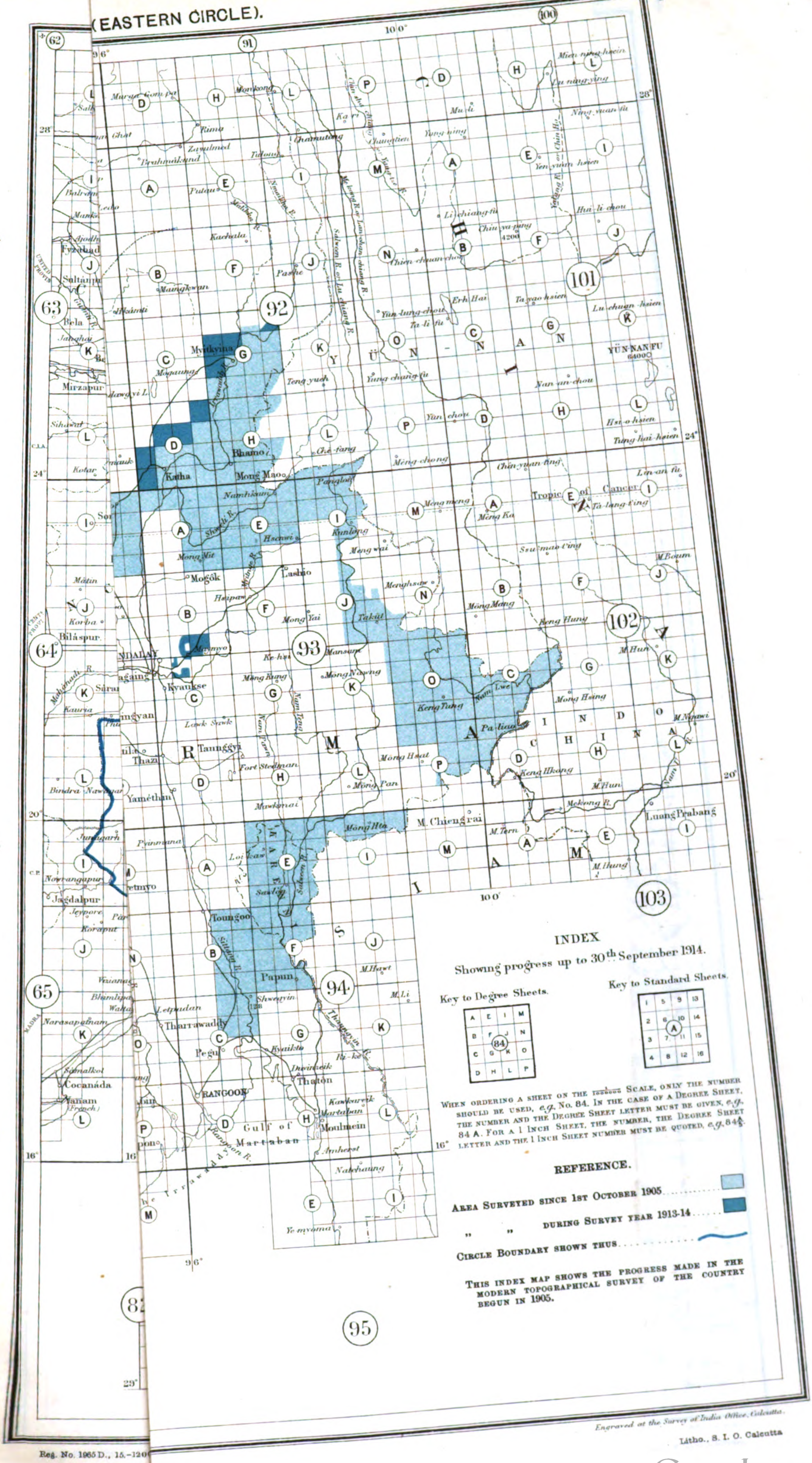
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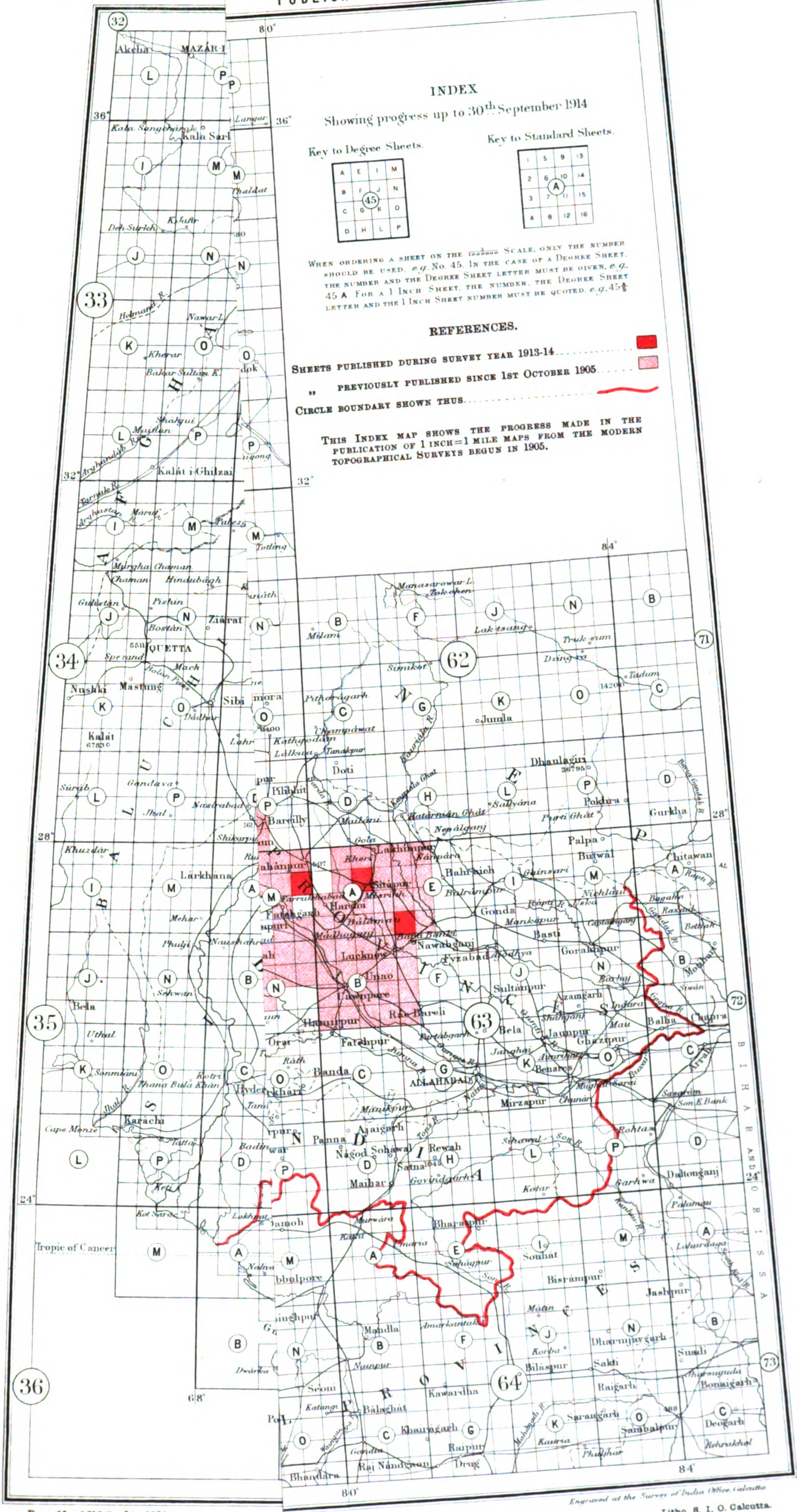

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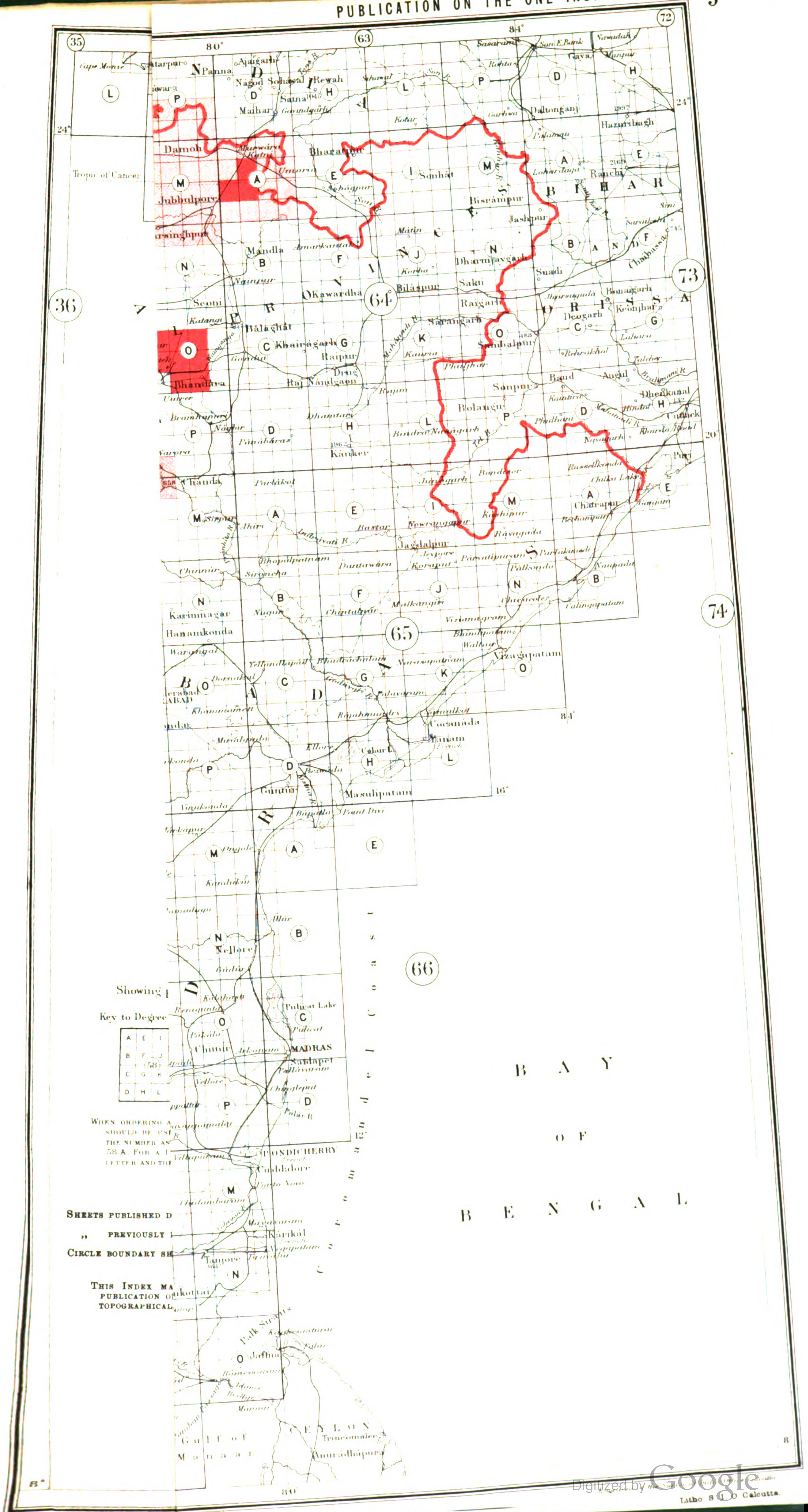

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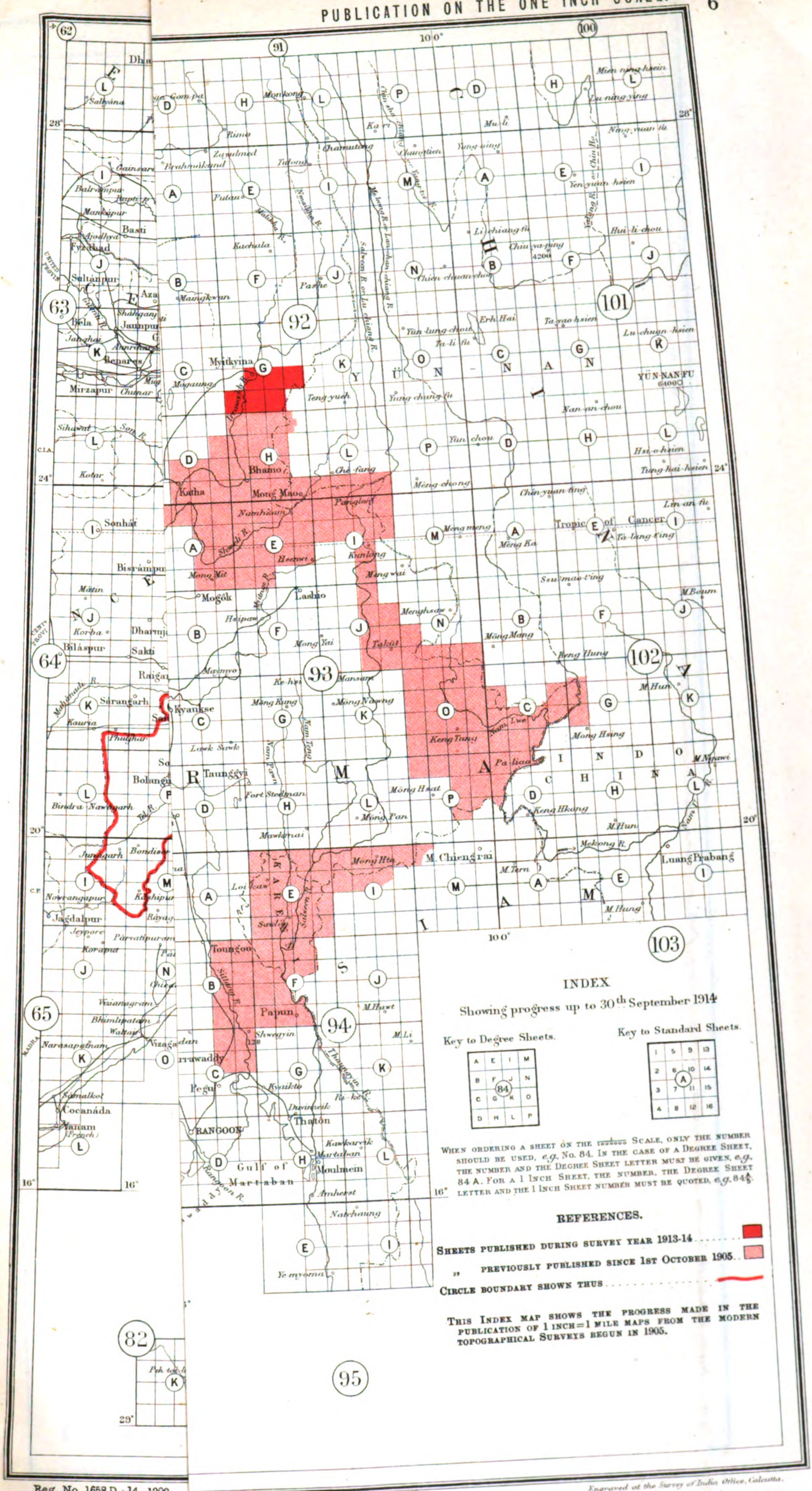

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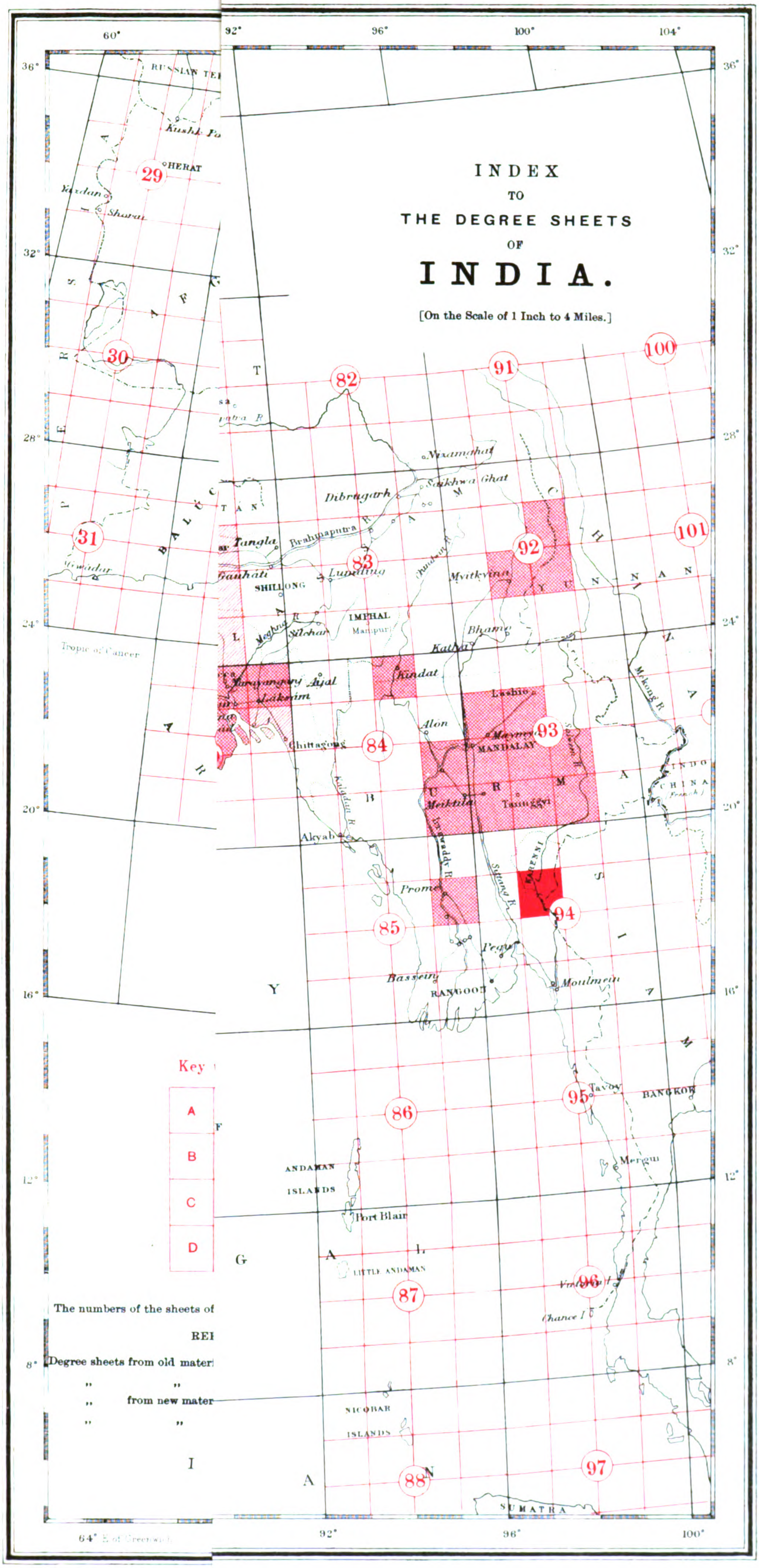

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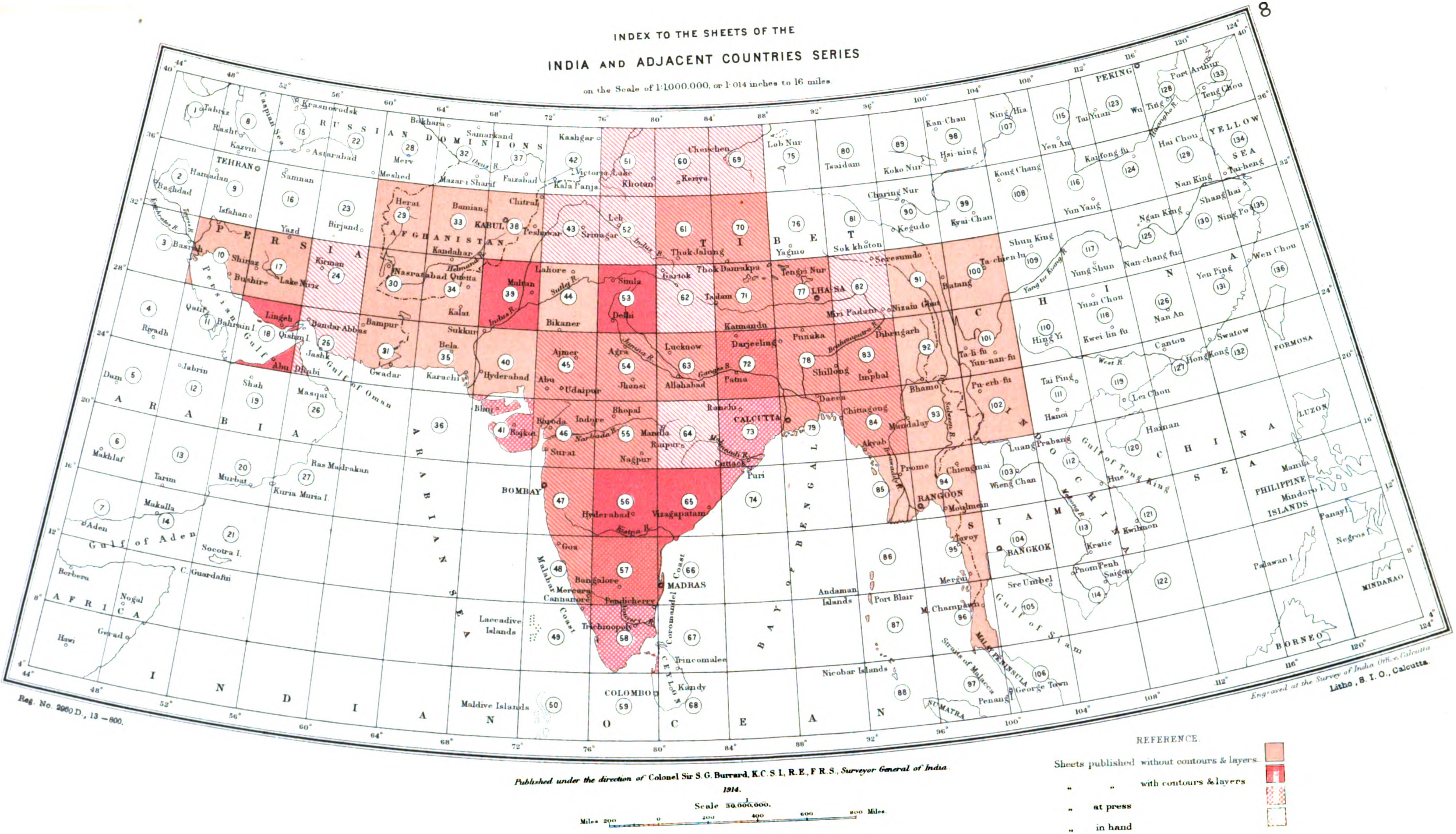
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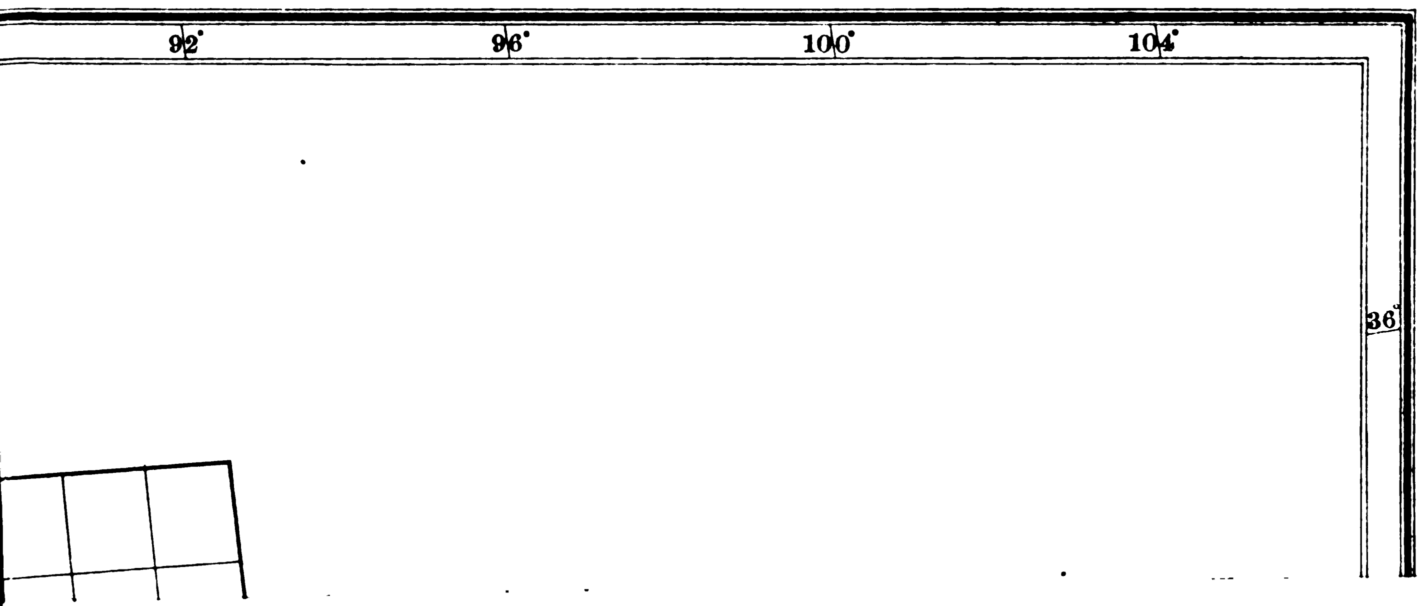
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